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Issued August 7, 1907.

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 189.

A. C. TRUE, Director.

REPORT

ON THE

DRAINAGE OF THE EASTERN PARTS OF CASS, TRAILL, GRAND FORKS, WALSH, AND PEMBINA COUNTIES, NORTH DAKOTA.

BY

JOHN T. STEWART,

Drainage Engineer, Irrigation and Drainage Investigations.

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*Bul. 36. Notes on Irrigation in Connecticut and New Jersey. By C. S. Phelps and E. B. Voorhees. Pp. 64.

*Bul. 58. Water Rights on the Missouri River and its Tributaries. By Elwood Mead. Pp. 80.

Bul. 60. Abstract of Laws for Acquiring Titles to Water from the Missouri River and its Tributaries, with the Legal Forms in Use. Compiled by Elwood Mead. Pp. 77.

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*Bul. 104. The Use of Water in Irrigation. Report of investigations made in 1900, under the supervision of Elwood Mead, expert in charge, and C. T. Johnston, assistant. Pp. 334. (Separates only.)

*Bul. 105. Irrigation in the United States. Testimony of Elwood Mead, irrigation expert in charge, before the United States Industrial Commission, June 11 and 12, 1901. Pp. 47.

*Bul. 108. Irrigation Practice among Fruit Growers on the Pacific Coast. By E. J. Wickson. Pp. 54.

Bul. 113. Irrigation of Rice in the United States. By Frank Bond and George H. Keeney. Pp. 77.

Bul. 118. Irrigation from Big Thompson River. By John E. Field. Pp. 75.

*Bul. 119. Report of Irrigation Investigations for 1901, under the direction of Elwood Mead, chief. Pp. 401. (Separates only.)

Bul. 124. Report of Irrigation Investigations in Utah, under the direction of Elwood Mead, chief, assisted by R. P. Teele, A. P. Stover, A. F. Doremus, J. D. Stannard, Frank Adams, and G. L. Swendsen. Pp. 336.

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Bul. 131. Plans of Structures in use on Irrigation Canals in the United States, from drawings exhibited by the Office of Experiment Stations at Paris, in 1900, and at Buffalo, in 1901, prepared under the direction of Elwood Mead, chief. Pp. 51.

*Bul. 133. Report of Irrigation Investigations for 1902, under the direction of Elwood Mead, chief. Pp. 266.

Bul. 134. Storage of Water on Cache la Poudre and Big Thompson Rivers. By C. E. Tait. Pp. 100.

[Continued on third page of cover.]

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THE OFFICE OF EXPERIMENT STATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., May 1, 1907.

Sir: I have the honor to transmit herewith a report on the drainage of the eastern parts of Cass, Traill, Grand Forks, Walsh, and Pembina counties, North Dakota, prepared by John T. Stewart, drainage engineer, under the direction of Dr. Elwood Mead, chief of the Irrigation and Drainage Investigations of this Office.

The areas surveyed are in the valley of the Red River of the North and have very little fall, so that in many years they are too wet for crop production. Replies to inquiries, representing 3,000,000 acres in this part of the valley, show that in 1905 there was a total loss of crop on about 260,000 acres which were seeded, while other large areas could not be plowed and seeded, running the losses for a single year from inadequate drainage into millions of dollars.

The surveys here reported were made for the purpose of determining the feasibility of draining the valley, the location and sizes of drains necessary, and the cost of their construction. The work was done by this Office with the cooperation of the State of North Dakota, the counties in which the surveys were made, and the Great Northern Railway Company. Each of the counties has been supplied with a typewritten copy of the part of the report relating to its territory and with a map showing the proposed ditches, but it is believed that the circulation of the complete report in the territory covered will be a great aid in securing the construction of the drains necessary to the protection of these lands. This section is typical of many river bottom areas, and the general discussion will be of great value to such sections by suggesting methods for their reclamation. The publication of the report as a bulletin of this Office is therefore recommended.

Very respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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DRAINAGE OF THE EASTERN PARTS OF CASS, TRAILL, GRAND FORKS, WALSH, AND PEMBINA COUNTIES, NORTH DAKOTA.

INTRODUCTION.

The lack of comprehensive plans for drainage in the valley portions of the counties in North Dakota bordering the Red River of the North has often seriously retarded needed drainage of farm lands in that section. This fact was brought to the attention of the delegates to the Second State Irrigation Convention, held at Bismarck, N. Dak., in January, 1905. A resolution was passed by that body requesting that the Office of Experiment Stations of the United States Department of Agriculture render assistance by making surveys, plans and reports for the guidance of landowners and district engineers in constructing drainage ditches. In compliance with this request a proposition was made to the commissioners of counties bordering the river, through Dr. J. H. Worst, director of the State experiment station, to make a topographic survey for drainage, provided the counties would contribute one-half of the estimated expense. Agreements between the Office of Experiment Stations and county commissioners of Cass, Traill, Grand Forks, and Walsh counties were entered into on this basis, a definite estimate of the cost of the proposed survey being named by the Office of Experiment Stations. The State engineer also agreed to assist through the services of the assistant State engineer. Surveys were made in these four counties in 1905 as represented on the accompanying maps, and a report with plans and estimates was filed with the auditor of each of the counties.

A cooperative agreement was made in 1906 with the board of commissioners of Pembina County for a similar survey, based upon an estimate of $2,700 as the cost of the survey of the portion of the county represented on the map accompanying this report. The county agreed to contribute an amount not exceeding $700; the Great Northern Railway, $900; the State engineer's office, the services of the assistant State engineer, and the Office of Experiment Stations the balance. The work was to be performed under the supervision of the Office of Experiment Stations, as was the case in the survey of the four counties made the previous year. The survey of this county was completed in August, 1906, and a map and typewritten report of the survey has been prepared and transmitted to the auditor of that county.

The writer had charge of the work in the five counties, and has prepared a report and estimates of the cost of the work recommended. Mr. T. R. Atkinson, assistant State engineer, served as field engineer throughout the work and platted the field data of Cass, Traill, Grand Forks, and Walsh counties. The description of the manner in which the field work was performed and the total cost of the work, together with the portion of the expense borne by each of the contributing parties, are shown elsewhere in the report.

GENERAL CONDITIONS.

These five counties are situated in the eastern part of the State, adjacent to the Red River of the North, the valley portion of which comprises a strip of land 15 to 40 miles wide and 163 miles long. The soil is noted for its fertility, and when not damaged by excessive rain or by the spring overflows (resulting from melting snow) produces abundant crops of hard wheat of a superior quality; but in recent years lack of adequate drains has resulted in discouraging losses of crops and has checked the progress of permanent improvements. Experience here as well as elsewhere has taught that new land requires less drainage to produce good crops than land which has been cultivated for a number of years and that the necessity for drainage is likely to increase rather than diminish as the country becomes more densely populated.

Since the general drainage conditions in the five counties are similar, a discussion of the subject with slight modifications to meet local conditions will apply to each. This portion of the valley, because of its peculiar situation, is frequently overflowed by the rainfall from an extensive area occupying a higher level, adjoining it on the west. This more elevated area comprises 16,400 square miles, while the area on the bottom itself does not exceed 2,500 square miles. The drainage water from the west enters the river plain through well-defined channels, which either lose their identity by discharging their water over the level land or continue across the bottom lands through small and obstructed channels and frequently overflow. The banks of the natural streams are in many places 3 or more feet higher than the general level of the adjoining lands, so that when the water of the streams recedes it is impossible for the overflow to return directly to the channels. While the normal annual rainfall is about 22 inches, as will be noted from a study of the rainfall table (p. 16), it is unevenly distributed. During the last ten years a large part of these level lands has been excessively wet at times, entailing great loss to farmers, rendering the highways impassable, and retarding the prosperity of the entire valley. The lack of adequate outlet streams and channels makes individual efforts to construct drains ineffective without such cooperation of landowners as is provided for by the State drainage law.

The losses to this portion of the valley for the year 1905, as ascertained by A. L. Fellows, State engineer, and reported to the drainage convention held in Grand Forks in January, 1906, indicate in some measure the necessity of drainage and its approximate value to farmers. The following figures were obtained in answer to letters addressed to farmers in the valley, the replies representing an area of 3,000,000 acres:

Acres that could not be seeded	89, 234
Acres that could not be summer-fallowed	70, 187
Acres seeded and not worth harvesting	87, 035
Acres too wet to be plowed in the fall	166, 625
Acres which grew a crop but were too wet to be harvested	171, 493

It is further pointed out that adding the amount seeded but not worth cutting to that which was too wet to be harvested, there was a total loss of crop on 253,660 acres which, estimated at the average production of 15 bushels of wheat per acre and at 70 cents per bushel, gives a loss on this item alone of $2,663,407. These figures show the possible economic value of drainage to this valley and suggest what the landowners can afford to pay for it. As a further encouragement it should be observed that wherever land drainage has been carried out elsewhere on an extensive scale and in a thorough manner some or all of the following benefits have been obtained:

(1) The greater certainty of a full crop.
(2) Increase in acreage and also in the yield per acre.
(3) A permanent increase in the market value of the land.
(4) Benefits to the public roads.
(5) Benefits to railroads because of increased tonnage of freight.
(6) Benefits to nearby towns because of increased business.
(7) Benefits to public health and general welfare.

Every large drainage proposition presents three sets of problems of equal importance, each of which must be carefully considered. The first of these is the legal problems which will arise during the organization and establishment of the drainage district. The second comprises the problems relating to the provision of funds for prosecuting the work and maintaining an economical administration of the affairs of the organization. The third involves the engineering features which include the size and location of the ditches, their grade, slope, construction, and maintenence, and engineering data essential to the planning and construction of drainage works. These are coordinate problems, each of which should receive careful consideration.

It is the purpose to present here the engineering and other related problems that pertain to the drainage of these counties. A careful examination and a survey of the area have been made and data requiring exhaustive and patient research have been collected. Not only the area to be drained, but the extent and character of the contributing watershed were ascertained and its topographic features considered. The slope of its surface, the depth and character of the soil, the number, size, and condition of the natural water courses, their general direction, and the sufficiency of their banks, as well as the climatic conditions peculiar to that region, have been considered in planning the drainage of the valley.

GENERAL TOPOGRAPHY AND THE SUFFICIENCY OF THE NATURAL STREAMS FOR DRAINAGE OUTLETS.

The outlet for the drainage of the territory under consideration is the Red River of the North, which rises in Lake Traverse and flows north, forming the boundary between Minnesota and North Dakota. It has an average fall of about 6 inches per mile, and has a tortuous channel winding in short loops back and forth across a strip of country almost a mile wide. It has a range of 16 to 50 feet between high and low water and at times overflows its banks in places. This usually occurs in the spring, when the ground is frozen and the run-off excessive by reason of the sudden melting of the snow at a time when the channel is obstructed by snow and ice. When the water in the river reaches the level of the land adjoining, it retards the drainage of the entire valley, particularly the area near the stream, and causes many of the tributary streams to overflow their banks. The physical features of this river, as compiled from the reports of the engineering corps of the Army and from other sources, are represented in the following table:

Physical features of Red River of the North, by sections.

From—	To—	Distance by river.	Distance by direct line.	Total fall.	Average fall per mile.	Width of channel.	Height of bank.	Range between high and low water.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Wahpeton........	Abercrombie.....	26.0	14.0	35.5	1.36	125	12	16
Abercrombie.....	Fargo............	71.0	30.0	38.2	.54	95	37	33
Fargo...........	Goose Rapids....	98.1	41.0	50.6	.51	100	38	33
Goose Rapids....	Belmont.........	21.9	11.0	21.2	.97	160	61	40
Belmont.........	Grand Forks.....	35.0	22.0	12.8	.36	100–200	60	50
Grand Forks.....	Turtle River.....	25.0	18.0	6.2	.40	....	45	45
Turtle River.....	Salt River.......	30.5	13.0	18.8	.29	250–300	40	40
Salt River.......	Pelican River....	40.0	17.0	11.9	.29	....	45	40
Pelican River....	Boundary line...	48.0	28.0	9.3	.19	....	50	38
Total........	....	395.5	19.40	194.5	.49	....	....	....

The question arises as to the ability of this stream to receive and carry away the drainage from the area under consideration. During the summer of 1905, when the survey of the territory was made, the zero points of the gauges established along the river were connected with the general level system and referred to the common datum, and the elevation of the water surface of the various streams was taken. The following comparisons of the low water levels of the streams, and the surface of the land adjoining them, show the depths which the streams could carry without overflowing:

Comparison of the elevation of the water surface of the streams with the land surface near them.

CASS COUNTY.

Stream.	Water surface.	Land surface.	Difference.
	Feet.	*Feet.*	*Feet.*
Red River at south boundary, Cass County	882.8	924.0	41.2
Wild Rice River at south boundary, Cass County	895.0	924.0	29.0
Sheyenne River at northwest corner section 1, of Norman Township	905.9	919.0	13.1
Red River at Fargo	868.0	901.0	33.0
Sheyenne River near southeast corner section 7, of Barnes Township	886.9	899.0	12.1
Maple River at Mapleton	896.0	906.0	10.0
Red River at line between Harwood and Wiser townships, Cass County	850.7	882.7	32.0

WALSH COUNTY.

Red River at section 24, Walshville Township	778.6	807.0	28.4
Forest River, section 14, Forest River Township	826.6	839.0	12.4
Red River at southeast corner section 24, St. Andrews Township	764.6	791.0	26.4
Park River near Grafton	803.2	828.0	24.8

GRAND FORKS COUNTY.

Red River at Grand Forks	786.0	835.0	49.0
Turtle River at North line of Rye Township	816.6	838.0	21.4

Highest and lowest gauge readings, in feet, at points on the Red River and its tributaries where records have been kept.

[From reports of U. S. Geological Survey.]

RED RIVER AT GRAND FORKS, N. DAK.

[Elevation of zero of river gauge = 781.43.]

Year.	Gauge.	Date of highest water.	Gauge.	Date of lowest water.	Year.	Gauge.	Date of highest water.	Gauge.	Date of lowest water.
	Feet.		*Feet.*			*Feet.*		*Feet.*	
1896	32.0	May 30	5.6	Oct. 8	1901	26.2	Apr. 6	6.2	Sept. 24
1897	50.2	Apr. 10	6.9	Nov. 13	1902	26.0	Mar. 30	5.9	Oct. 23
1898	15.0	Apr. 14	5.4	Nov. 13	1903	27.9	Apr. 11	5.0	Aug. 24
1899	20.9	Apr. 17	5.7	Nov. 11	1904	40.6	Apr. 27	6.0	Aug. 30
1900	16.5	Oct. 13	3.4	July 1	1905	26.2	May 18	7.4	May 1

RED RIVER AT FARGO. N. DAK.

[Elevation of zero of river gauge = 863.14.]

1902	10.5	May 25	6.8	Nov. 30	1904	21.3	Apr. 20	7.0	Nov. 29
1903	13.9	Apr. 6	7.0	Aug. 24	1906	10.5	May 23	6.8	Nov. 30

Highest and lowest gauge readings, in feet, at points on the Red River and its tributaries where records have been kept—Continued.

SHEYENNE RIVER AT HAGGART, N. DAK.

[Elevation of zero of river gauge = 880.92.]

Year.	Gauge.	Date of highest water.	Gauge.	Date of lowest water.	Year.	Gauge.	Date of highest water.	Gauge.	Date of lowest water.
1902..........	18.0	Apr. 10	3.4	Aug. 18	1904.........	18.4	Apr. 23	3.1	Aug. 30
1903..........	14.7	Apr. 11	3.0	Aug. 5	1905.........	9.8	May 13	3.8	Sept. 26

PEMBINA RIVER AT NECHE, N. DAK.

1904..........	20.9	May 2	4.5	Nov. 18	1905.........	9.0	June 11	2.9	Aug. 30

RED LAKE RIVER AT CROOKSTON, MINN.

1902..........	10.0	May 21	4.6	July 29	1904.........	20.3	Apr. 24	3.7	Nov. 28
1903..........	7.6	June 1	4.1	Aug. 11	1905.........	14.1	May 13	4.1	Dec. 2

OTTER TAIL RIVER AT FERGUS FALLS, MINN.

1904..........	3.8	June 6	3.0	Sept 14	1905.........	3.9	Aug. 10	2.8	Apr. 11

Daily gauge height, in feet, of the Pembina River at Neche, N. Dak., from April 1 to September 30, for the years 1904 and 1905.

[Elevation of zero of gauge = 813.33.]

Day.	April.		May.		June.		July.		August.		September.	
	1904.	1905.	1904.	1905.	1904.	1905.	1904.	1905.	1904.	1905.	1904.	1905.
1..........	......	6.20	20.7	4.70	10.2	4.60	8.1	5.30	6.0	3.45	5.5	3.00
2..........	......	6.30	20.9	4.60	9.9	4.60	7.9	5.10	6.0	3.45	5.5	3.00
3..........	......	6.30	20.7	4.50	9.9	4.60	8.9	5.00	6.0	3.45	5.5	3.00
4..........	3.7	8.20	20.3	4.40	9.9	4.60	15.2	4.90	6.0	3.45	5.5	2.95
5..........	3.8	9.80	19.9	4.30	14.0	4.60	16.0	4.70	6.0	3.45	5.5	2.95
6..........	4.0	9.50	19.3	4.20	13.8	4.60	11.8	4.50	6.0	3.40	5.5	3.00
7..........	4.5	8.60	18.6	4.40	13.3	6.40	9.7	4.40	6.0	3.50	5.5	2.95
8..........	5.0	7.50	18.0	4.80	12.0	6.20	9.5	4.40	6.0	3.60	5.5	2.95
9..........	7.0	7.50	17.4	4.80	11.0	6.00	8.6	4.30	6.0	3.50	5.5	3.00
10..........	9.3	7.50	16.8	5.00	11.8	9.00	8.0	4.30	6.0	3.40	5.5	3.05
11..........	9.4	7.00	16.4	5.00	13.8	9.00	7.8	4.20	5.9	3.35	5.5	3.10
12..........	10.0	6.50	16.0	5.90	15.2	9.00	7.6	4.10	5.9	3.30	5.5	3.15
13..........	11.7	6.00	16.5	9.00	15.3	8.10	7.6	4.00	5.8	3.30	5.5	3.25
14..........	12.2	5.40	16.9	8.60	14.0	6.60	7.3	4.00	5.8	3.25	5.4	3.30
15..........	13.5	5.00	17.5	8.00	12.8	5.60	7.0	3.90	5.8	3.25	5.4	3.35
16..........	13.8	5.00	17.7	7.40	12.0	5.30	6.9	3.90	5.8	3.25	5.4	3.35
17..........	12.9	5.00	16.3	7.00	11.3	5.00	6.9	3.90	5.8	3.30	5.3	3.35
18..........	11.8	5.00	15.4	6.20	10.5	5.00	6.9	3.90	5.7	3.30	5.3	3.40
19..........	12.4	4.90	14.6	6.00	10.4	4.90	6.8	3.90	5.7	3.30	5.4	3.40
20..........	15.3	4.90	14.1	5.80	9.7	4.90	6.8	3.90	5.7	3.25	5.4	3.35
21..........	16.2	4.80	13.9	5.60	9.5	4.90	6.8	3.80	5.9	3.20	5.5	3.35
22..........	16.8	4.80	13.3	5.50	13.1	5.00	6.8	3.80	5.9	3.15	5.5	3.35
23..........	17.0	4.80	13.3	5.30	13.2	5.00	6.7	3.80	5.9	3.10	5.5	3.35
24..........	17.8	4.80	13.0	5.00	13.4	4.90	6.5	3.75	5.9	3.05	5.5	3.35
25..........	18.0	4.80	12.5	4.80	12.7	5.10	6.2	3.70	5.8	3.00	5.5	3.30
26..........	18.2	4.80	12.0	4.90	11.1	5.40	6.0	3.70	5.7	3.00	5.4	3.40
27..........	18.2	4.80	11.8	4.90	10.3	5.50	6.0	3.60	5.7	3.00	5.4	3.40
28..........	18.3	4.80	11.4	4.90	9.1	5.40	6.0	3.50	5.6	2.95	5.3	3.40
29..........	19.0	4.80	11.1	4.80	8.4	5.40	5.9	3.50	5.5	2.95	5.2	3.45
30..........	19.7	4.80	10.8	4.60	8.3	5.40	6.0	3.50	5.5	2.90	5.1	3.45
31..........	......	......	10.5	4.60	......	......	6.0	3.45	5.5	2.95	......	......

After heavy rains the land was saturated in places, some wheat fields being covered with water to a depth of 3 or more inches and many of the roads impassable. The same condition prevailed on the Minnesota side of the river. The levels above given show that during this time there was ample capacity for water in the Red River and also in its several tributaries. It is safe to say that had the land been traversed with properly located ditches of sufficient size, the river would have afforded all the outlet capacity required without causing an overflow of its banks at any point. This can not be said of the early spring floods caused by rain and melting snow. The volume of water delivered to the river at these seasons is frequently greater than during the summer. The channel is often partly filled with snow and ice, resulting in floods which damage town properties along the river far more than the farms situated some distance back from the stream. It is doubtful if any improvement of the stream, except the removal of bridge piles and other obstructions from the channel, will lessen the damages from the spring overflow of the river along the borders of the stream unless an elaborate straightening and improvement of the channel be carried out. Such improvements, however, are not essential to the successful operation of drainage ditches during the growing season of the year.

The topography, as ascertained by the survey and represented on the map, merits a close inspection. The slope varies in direction from south and east to east and north, by far the larger area having the greatest surface slope to the northeast. The river banks are 3 and 4 feet higher than the general level of the land a short distance from the stream. Parallel to the river and 1 to 2 miles west of it is a strip of land which is the lowest and flattest in the valley. From the edge of this belt the valley begins to rise 1 to 3 feet per mile, and the slope increases toward the western limit of the area surveyed, at which point it is not uncommon to find a rise of 15 to 20 feet per mile. The slope of the valley parallel to the general direction of the river is in many localities 1 foot or less per mile. It is not uncommon to find small tracts with a slope opposite to that which prevails over the surrounding area. In the southern part of Cass County there are three distinct basins with a fall nearly due north, while in the northern part of Walsh County there is an area which slopes to the south. As a rule, the general direction of the coulées[a] and streams indicates the direction of the greatest surface slope. The banks of the coulées, as well as of the streams, are higher than the surface of the land a short distance away. This peculiarity is caused by repeated overflows which have taken place during the formation of the streams. The current of each stream, which is highly charged with sediment, is slackened when it overflows the banks, depositing the larger quantity of sediment where the water first leaves the channel. This occurs year after year, gradually raising the banks above the level of the surrounding prairie. This characteristic of coulées greatly restricts their value as drainage channels. Both streams and coulées, which are the only natural water channels, are usually narrow, crooked, and obstructed in many places by drift and growing trees. Trees, partially undermined by erosion, have fallen across the channels, and brush and small trees grow to the low-water lines. In some instances piles for highway bridges have been driven in such positions that they gather large quantities of drift. These conditions, in addition to the crookedness of the channels, greatly reduce their flood capacity, though of course they occasion no serious difficulties during low water periods.

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[a] The word "coulée" is used in this bulletin in its local sense.

A passing notice should be given to the attempts that have been made at artificial drainage. With few exceptions, the ditches so far constructed have been made along the public highways by means of road machines, without reference to regular grades, adequate size, or final outlets. They are not satisfactory, because they are too small to serve the areas to be drained, and frequently overflow at points where they spread their waters over farm land which occupies a lower level, greatly to its injury. Attempts have been made to increase the carrying capacity of some of the ditches by throwing up small levees on the sides, but no permanent benefits have been derived from the practice. The water from the highlands fills the ditches, which, lacking sufficient size and outlet, overflow and distribute their water over a wide area of farm lands. Ignorance in regard to the surface slope has led to faulty location of many drains, resulting in injury rather than benefit and engendering costly litigation and opposition to organized drainage improvement.

TEMPERATURE.

Records of temperature have been kept at various points in the valley since 1859, although not continuously. According to the reports of the United States Weather Bureau, the Red River Valley is both the warmest region in the summer and the coldest in the winter of any section of North Dakota. The range between the annual maximum temperature and the annual minimum temperature is from 101° to 141° F. The extreme maximum occurs from June to August, ranging from 101° to 110° above zero. The extreme minimum occurs in January or February, ranging from 34° to 55° below zero. However, such periods of extremes do not occur often, and when they do they are of short duration.

The seasons are rather sharply defined, warm weather coming in April, when the mean temperature ranges from 37° to 46°, and increases on the average over one-half degree per day until June, when the mean ranges from 63° to 74°. The time of the latest killing frost in the spring varies from March 17 to June 24, the average date being about May 14. The first killing frost of the fall varies from August 4 to September 30, the average date being about September 10. Winter begins in November, when the ground usually freezes sufficiently to stop plowing.

The Red River was closed to navigation by ice in the years 1881 to 1888 at dates varying from November 11 to 25, and in the years 1895 to 1901 at dates varying from November 6 to December 3, the average date being November 17, while navigation opened by the river being free from ice in the years 1881 to 1888 at dates varying from April 12 to 24, and in the years 1895 to 1901 from April 7 to April 18, the average date being April 14.

The snowfall varies from 7 to 57 inches, with an average of about 24 inches. Frost has been found in the ground as late as June 20, and it is not an unusual thing for the ground to freeze to a depth of 7 feet.

The spring seeding is done immediately after the growing season opens, when the ground is thawed to a depth of only a few inches. The valley is fully exposed to all air currents. Winds, usually light but on many days heavy, are moving almost continuously, with variations in their direction to every point of the compass.

RAINFALL.

It is a matter of common observation that wet and dry seasons occur in cycles of greater or less numbers of years. The precipitation for a number of years in succession may be deficient or not above the normal, during which time little or no artificial drainage is required. Such a period is usually followed by years in which the rainfall exceeds the average or, if it does not, the moisture conditions for a month or two during the cropping season may be so unfavorable as to occasion serious loss of crops.

The rainfall over the North Dakota watershed of the Red River from 1895 to 1904, inclusive, which is important in considering the drainage of the valley lands, has been compiled from the records of the United States Weather Bureau for Milton, Cavalier County, Grand Forks, and Power, Richland County. These records are given in the following tables. The rainfall records for 1905 for a number of other stations in the valley are also given.

Total rainfall, number of days of rainfall, and maximum rainfall in 24 hours, for each month of the years 1895 to 1904, inclusive, at Power, Richland County, N. Dak.

Month.	1895.			1896.			1897.		
	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.
	Inches.		*Inches.*	*Inches.*		*Inches.*	*Inches.*		*Inches.*
January	0.75	9	0.20	0.66	8	0.25	0.65	5	0.30
February	.52	4	.40	1.02	6	.80	1.10	5	.60
March	Trace.			1.21	7	.60	.55	3	.40
April	1.13	6	.61	4.18	14	1.55	Trace.		
May	1.04	11	.49	3.23			.88	4	.51
June	3.26	8	1.26	3.52	5	1.51	6.20	11	1.98
July	6.36	11	2.25	1.50	8	.46	7.54	6	3.80
August	2.94	10	1.10	2.02	9	.54	1.01	5	.43
September	1.13	6	.42	3.38	7	2.73	.22	2	.12
October	.17	4	.10	1.57	6	1.16	1.91	3	.70
November	1.31	8	.50	1.83	11	53	.10	1	.10
December	.18			.25	3	.10	.20	3	.10
Total	18.79			24.37			20.36		

Month.	1898.			1899.			1900.		
	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.
	Inches.		*Inches.*	*Inches.*		*Inches.*	*Inches.*		*Inches.*
January							0.22	4	0.07
February	0.20	2	0.10	0.25	3	0.10	.37	4	.15
March	.35	2	.20	1.65	6	.40	.61	2	.46
April	2.81	4	1.90	.50	2	.30	1.32	3	.73
May	2.31	5	.82	2.63	5	.96	.61	4	.27
June	2.36	7	.81	4.14	9	1.12	2.39	9	.54
July	3.39	3	2.28	2.34	5	1.10	.87	4	.69
August	2.52	4	1.19	2.92	6	1.20	6.04	10	1.71
September	.72	4	.32	.72	2	.51	2.88	5	1.06
October	1.10	2	.80	.96	4	.46	1.94	5	.70
November	.40	1	.40	Trace.			.46	8	.10
December	.02	1	.02	.20	1	.20	.25	2	.20
Total							17.96		

Month.	1901.			1902.			1903.			1904.		
	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.
	Inches.		*Inches.*	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*		*Inches.*
January	0.32	5	0.10	0.35	4	0.15	0.70	4	0.50	0.32	5	0.15
February	.20	1	.20	.66	5	.40	.92	5	.60	.85	6	.25
March	1.20	7	.47	1.78	5	.70	.40	5	.10	.82	5	.50
April	1.70	5	.84	2.17	4	1.41	1.34	6	.52	2.82	6	1.27
May	.17	5	.07	3.86	10	.88	3.23	3	1.71	1.01	5	.37
June	5.78	13	1.44	2.66	10	.75	.74	8	.16	7.59	11	1.90
July	8.14	6	6.36	1.73	6	1.10	2.82	7	.87	3.22	8	.98
August	1.33	7	.35	3.56	8	1.05	4.29	7	1.10	.71	6	.22
September	3.01	5	1.82	.65	4	.30	2.76	7	1.26	3.21	7	1.26
October	3.24	5	2.17	4.81	5	2.25	.97	5	.46	1.62	4	.74
November	.20	1	.20	.25	1	.25	.10	1	.10	.02	1	.02
December	.82	4	.60	.40	2	.30	.10	2	.05	.75	5	.30
Total	26.11			22.88			18.37			22.94		

July 5 to 7, 1895, inclusive, 4.69 inches fell.
July 19 to 20, 1897, inclusive, 6.55 inches fell.
October 23 to 25, 1902, inclusive, 4.26 inches fell.
April 7 to 8, 1904, inclusive, 2.47 inches fell.

Total rainfall, number of days of rainfall, and maximum rainfall in 24 hours, for each month of the years 1895 to 1904, inclusive, at University, Grand Forks, N. Dak.

Month.	1895.			1896.			1897.		
	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.
	Inches.		*Inches.*	*Inches.*		*Inches.*	*Inches.*		*Inches.*
January	0.31	4	0.18	0.50	5	0.20	0.65	4	0.25
February	3.00	6	2.00	.15	4	.10	.92	8	.30
March	.05	1	.05	.46	5	.40	.78	5	.40
April	.93	9	.51	5.69	10	1.06	.56	6	.12
May	1.94	11	.84	7.92	15	3.13	1.76	8	.72
June	6.74	17	1.56	2.25	7	.69	......	......	......
July	2.69	13	1.13	.53	8	.20	6.44	6	3.85
August	1.54	10	.36	1.53	10	.40	1.72	3	1.33
September	1.57	13	.72	1.39	7	.43	.10	1	.10
October	.56	6	.40	1.12	5	.80	.85	3	.55
November	1.58	9	.53	2.10	7	.60	.29	5	.14
December	.34	......	......	.50	4	.30	.24	4	.18
Total	21.25	......	......	24.14	......	......	......	......	......

Month.	1898.			1899.			1900.		
	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.
	Inches.		*Inches.*	*Inches.*		*Inches.*	*Inches.*		*Inches.*
January	0.10	5	0.04	0.60	4	0.30	0.11	3	0.05
February	.86	4	.40	.10	1	.10	.27	6	.08
March	.57	9	.40	.60	3	.30	.35	3	.15
April	4.16	6	3.48	4.20	4	1.74	1.22	4	.63
May	2.32	5	.90	6.11	8	1.78	.25	2	.20
June	6.80	3	3.00	......	......	......	.88	......	......
July	3.76	6	2.50	2.10	2	1.50	1.17	5	.70
August	1.35	5	.37	1.55	4	.65	6.98	10	2.25
September	2.26	4	.92	......	......	......	4.90	6	2.21
October	1.23	3	1.00	1.55	4	1.25	2.81	12	1.10
November	Trace.	......	......	.39	3	.15	.90	3	.60
December	.50	4	.30	.50	3	.30	.20	1	.20
Total	23.91	......	......	......	......	......	20.04	......	......

Month.	1901.			1902.			1903.			1904.		
	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.
	Inches.		*Inches.*	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*		*Inches.*
January	......	......	......	0.31	3	0.13	0.70	7	0.20	0.30	......	......
February	0.20	2	0.20	.59	7	.25	.10	2	.05	1.10	6	0.30
March	.65	5	.20	1.74	9	.97	.51	......	......	1.08	7	.30
April	2.06	8	.80	2.46	5	1.30	.75	3	.55	1.53	6	.80
May	.28	2	.15	3.88	11	1.62	1.85	8	.90	1.70	5	.50
June	8.47	15	1.51	2.09	10	.80	.49	6	.19	5.64	13	1.40
July	4.18	......	......	2.94	4	1.22	2.12	7	1.08	2.01	6	.71
August	......	......	......	3.15	12	1.46	4.02	8	1.20	2.79	7	1.55
September	1.55	4	1.13	2.08	9	.55	3.55	4	1.95	1.91	7	.52
October	2.21	4	1.33	1.98	6	.99	1.95	4	1.60	2.49	7	1.66
November	.24	2	.16	.32	5	.17	.60	5	.30	Trace.	......	......
December	.71	10	.35	.46	6	.10	1.05	4	.50	.43	4	.20
Total	......	......	......	22.00	......	......	17.69	......	......	20.98	......	......

April 25 to 28, 1900, inclusive, 2.22 inches fell.
August 4 to 10, 1900, inclusive, 5.95 inches fell.

Total rainfall, number of days of rainfall, and the maximum rainfall in 24 hours, for each month of the years 1895 to 1904, inclusive, at Milton, Cavalier County, N. Dak.

Month.	1895.			1896.			1897.		
	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.
	Inches.		*Inches.*	*Inches.*		*Inches.*	*Inches.*		*Inches.*
January	0.50	4	0.10	0.50	2	0.30	0.65	5	0.20
February	.05	2	.05	.40	2	.30	1.10		
March	.10	1	.10	1.67	9	.40	1.00		
April	1.75	4	.75	7.43	10	2.50			
May	3.97	10	1.00	8.51	16	2.61	Trace.		
June	5.80	11	1.00	4.85	9	2.20	2.77	10	.67
July	3.30	7	1.10	1.75	4	.65	6.95	10	4.50
August	2.68	5	.90	2.90	6	2.00	1.20	4	.60
September	1.30	1	1.30	1.55	5	1.10	Trace.		
October	.11	4	.10	.00			1.00	4	.40
November	.60	6	.15	2.00	11	.60	.40	3	.20
December	.60			.55			.20	2	.10
Total	20.76			32.11					

Month.	1898.			1899.			1900.		
	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.
	Inches.		*Inches.*	*Inches.*		*Inches.*	*Inches.*		*Inches.*
January	0.30	2	0.20	0.50	3	0.30	0.20	2	0.10
February	.40	2	.30	.40	3	.20	.30	2	.20
March	.50	4	.20	.90	6	.20	.50	4	.20
April	.88	5	.30	3.00	8	.80	.60	2	.50
May				2.70	6	.75	.10	1	.10
June	3.70	6	1.50	3.35	8	.90	1.35	5	.75
July	2.42	4	1.00	3.30	3	2.00	3.80	5	2.90
August	1.70	3	.90	3.85	8	1.00	4.05	11	1.50
September	2.75	5	.90	1.60			7.30	9	1.90
October	1.11	5	.29	1.75	4	.90	.80	4	.40
November	.90	4	.30	.45	2	.40			
December	.30	2	.20	.20	2	.10	.40	3	.20
Total				22.00					

Month.	1901.			1902.			1903.			1904.		
	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.	Total rainfall.	Number days of rainfall.	Maximum rainfall in 24 hours.
	In.		*Inches.*	*In.*		*Inches.*	*In.*		*Inches.*	*In.*		*Inches.*
January	0.60	4	0.30	0.01	1	0.01	0.44					
February	.40	1	.40	.98	6	.40	.20	5	0.10			
March	1.65	6	.80	3.23	11	.99	.40	3	.20			
April	.93	5	.50	.54	4	.40				2.78	4	2.33
May	.20	1	.20	4.98	12	2.25	2.04	5	.68	1.94	6	.74
June	6.10	13	1.15	3.17	16	1.08	1.65	4	.83	8.23	8	3.13
July	5.23	7	3.00	1.49	8	.71	1.01	3	.57	4.27	7	2.00
August				.64	7	.20	4.76	10	.92	1.81	2	1.76
September	2.30	10	1.02	1.26	8	.35	2.65	3	1.30	1.76	4	1.65
October	.55	7	.20	.80	5	.38	1.63	2	1.60	1.56	2	1.50
November	.02	1	.02	.26	3	.10						
December	.23	5	.10	.58	5	.20				Trace.		
Total				17.94						22.35		

April, 1896, 28 to 30, inclusive, 5.25 inches fell.
May, 1896, 16 and 17, inclusive, 3.21 inches fell.
September, 1903, 11 and 12, inclusive, 2.34 inches fell.

Monthly precipitation for the year 1905 at various points in the North Dakota area of the Red River watershed.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Amenia	0.15	0.13	0.10	1.56	5.45	3.70	4.78	5.30	1.24	0.76	1.65	Trace.
Cooperstown	.10	.05	1.05	.89	2.89	5.00	4.85	4.58	.98	......	......	......
Fargo	.08	.20	.51	1.28	5.77	5.00	5.17	6.82	3.47	1.18	......	.05
Hamilton	.71	.33	2.50	.41	4.00	5.95	1.96	3.75	1.56	.26	3.06	1.10
Lisbon	.10	.10	.45	1.63	5.75	5.04	2.51	2.85	.63	1.03	1.64	Trace.
Mayville	.16	.05	.61	1.22	3.66	5.34	6.85	4.07	......	.42	......	.20
Minto	.38	.25	1.74	.41	3.67	4.55	5.03	6.37	3.68	.16	1.83	.19
Power	.45	.35	.59	1.40	6.09	3.95	4.74	6.13	1.87	.92	1.50	.32
Pembina	.68	.26	2.02	.39	4.09	4.46	.92	2.33	1.54	.69	.75	.57
Park River	.35	.04	1.36	.26	3.04	5.53	2.52	4.52	3.62	1.07	1.64	.37
University	.29	.13	2.35	.96	3.89	4.57	5.49	4.54	2.81	.28	2.35	.28
Wahpeton	.32	.35	.25	......	5.29	5.20	5.93	......	1.91	1.57	1.53	Trace.
Walhalla	.80	Trace.	1.81	Trace.	3.67	6.43	.76	3.14	1.97	Trace.	1.98	1.10

The uneven distribution of the precipitation is notable. There is one record of 6.3 inches and three of 4 inches in 24 hours. There are maximum monthly rainfalls of 5½ to 8½ inches, where the normal is only 2 to 3 inches. In the Grand Forks record for the year 1900 it is noted that from January to July, inclusive, the rainfall was only 4¼ inches, while for the following months of August and September it was 11.88 inches, the precipitation for the entire year being only 20.04 inches.

A further study of the rainfall records discloses a fact not usually recorded—that the maximum and monthly precipitation during the cropping season in the valley is not far different from that in the northern portions of the Mississippi and Ohio River valleys, where the annual rainfall is 98 to 44 inches and in which territory the drainage of all level lands is essential to their profitable agricultural use. The rainfall at Fargo during May, June, July, and the first fifteen days of August, 1905, was 4.10, 5, 5.17, and 5.14 inches, respectively, and the maximum monthly precipitation for the same months during the ten years preceding was 4.15, 5.91, 8.24, and 8.28 inches. The record kept at Wooster, Ohio, from 1888 to 1902, a period of fifteen years, shows the maximum monthly rainfall to range between 4.21 and 8.05 inches, and the annual between 30 and 54.2 inches. The annual rainfall in the Genesee Valley, New York, from 1890 to 1898, ranged between 30 and 47.8 inches and averaged 40.33 inches. The largest monthly rainfall recorded between 1882 and 1903 is 7.77 inches. This shows that the maximum monthly rainfall during the growing season is at times as great as it is in States where the annual rainfall is one-third greater.

A condition affecting the drainage of the valley lands in the spring season, but which does not appear from the rainfall record, makes artificial drainage a necessity even during seasons of well-distributed summer rainfall. The snowfall ranges from 7 to 57 inches in depth. The opening of spring accompanied by the usual rainfall, causes the snow to melt with greater or less rapidity, bringing to the stream and to the land the water accumulated from these two sources. Nearly all of this must pass over from the frozen surface, giving a very high percentage of run-off. Wheat is sown as early in the spring as the soil is in condition to receive the seed, and while the frost is still in the ground. The failure to remove the early spring water from the surface results in a delay in seeding, making late wheat, which is frequently frosted in the fall before it can ripen. The run-off at this season is more rapid than during the summer, since it passes over the frozen surface. If checked by obstructed ditches it spreads over the adjacent fields, filling every depression, so that at no time of the year is there a greater need for ditches so located as to remove the surface water from these depressions.

The fallacy of using the average run-off data and normal rainfall records in determining the size of drainage channels that should be provided has been demonstrated in almost every region where drainage of large areas has been attempted. The maximum water conditions must be met instead of either the average or usual. It is frequently stated that the soil of the valley has so large a capacity for water during the summer months and the evaporation from the surface is so great that little or no artificial drainage is required for these lands. Observation has repeatedly shown this conclusion to be erroneous. The State is indebted to its experiment station for careful observations along this line, which, when interpreted with reference to land drainage, give us information of value bearing directly upon this question. The weight and water capacity of the soil at the State station, which may be regarded as fairly representative of the valley, is given in a bulletin now out of print, as follows:

Weight and water capacity of typical Red River Valley soil.

Depth of sample.	Weight per cubic foot.	Water capacity, volume.
Inches.	*Pounds.*	*Per cent.*
1- 6	47.05	73.59
6-12	65.19	66.77
12-24	78.07	64.48
24-36	84.31	61.99
36-48	99.44	59.24

The average weight of the first 3 feet of soil, as ascertained by these experiments, is 72.8 pounds per cubic foot. This is the weight of the soil after all moisture has been removed. Its capacity for water is 65.5 per cent of its volume and represents the volume of water which an oven-dried soil will absorb in coming to a state of complete saturation.

The surface black loams of the bottom lands of many of the rivers of Illinois and Iowa will hold about 56 per cent of water by volume and the first 3 feet in depth about 52 per cent of water when fully saturated. The per cent most favorable to the growth of plants in both North Dakota and Illinois soils is approximately 32 per cent by volume. When the top 6 inches in depth of both varieties of soil is saturated the former contains 41 per cent and the latter 24 per cent more than is required for the best growth of crops, and this should be removed by drainage or by evaporation. This saturation does no injury to ordinary field crops if the surplus begins to move away promptly and continues to do so until a favorable state of soil moisture is reached, provided this is accomplished within a few days. However, stagnation of water in the soil is always injurious. It will be seen that the North Dakota soil will contain a larger percentage of water than many others before it becomes saturated, but when once in this condition the prompt removal of the excess is more urgent than it is for soils with less water capacity. Drainage should, as far as possible, prevent the complete saturation of the soil. Open ditches assist in doing this by removing the excess from the surface before it passes to the lower soil. This process supplies the lower soil with such moisture as is necessary and at the same time removes a part of the surplus, so that the surface is kept in a friable condition under the ordinary amount of precipitation. There are times when the precipitation is so heavy and continuous that both soil and subsoil become fully saturated, producing conditions that necessitate providing for the surface flood run-off by adequate ditches.

EVAPORATION.

Measurements were made at the agricultural college at Fargo to determine the daily loss from a water surface by evaporation. These were made from 1902 to 1905, inclusive, from May to September of each year, and the results are somewhat remarkable. The following averages compiled from the tables of evaporation and rainfall at that place for the same time show their relation:

Rainfall and evaporation at Fargo, N. Dak., 1902–1905.

	May.	June.	July.	August.	September.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Average monthly evaporation	5.390	6.330	8.240	7.450	3.430
Average monthly rainfall	3.610	3.120	3.320	3.750	3.290
Excess of average monthly evaporation over rainfall	1.780	3.210	4.920	3.700	.140
Average daily evaporation	.174	.211	.266	.240	.114
Average daily rainfall	.116	.104	.107	.120	.110
Excess of average daily evaporation over rainfall	.058	.107	.159	.120	.004

These evaporation tables, like many others which are quoted in connection with rainfall, may easily lead to erroneous conclusions. They show that loss by evaporation is considerably in excess of the rainfall.

It should be remembered that these are measurments of loss from a water surface under most favorable conditions for evaporation. No experiments at the college have determined this loss from a soil surface. From a study of the voluminous tables it is seen that on 9 per cent of the total number of days there was not sufficient evaporation to be recorded, while on the others it varies from 0.01 to 0.99 inch. On 53 per cent of the total number of days there was no rainfall, while on others it varies from a trace to 2.17 inches. Apparently there is no relation between the daily evaporation and the rainfall. Since humid days are unfavorable for evaporation, and windy days are highly favorable to it, it can be readily seen that a sultry day might not furnish any records of either evaporation or rainfall, while a heavy rainstorm lasting for several hours, followed by winds, would give a large precipitation and evaporation record for the same 24-hour period. The evaporation records show that the air has a great avidity for moisture at certain times, suggesting the wisdom of preventing this loss from a comparatively dry surface, while experience demonstrates it is only an uncertain aid in removing excessive rainfall or water from overflow, and fails at a time when most needed.

SIZE OF DITCHES.

The size of ditches used for the drainage of agricultural lands is more frequently determined by the ability of landowners to construct them, or by the limits imposed upon them by legal difficulties than by the physical conditions which must be met. Arguments in support of a ditch of inadequate size may appear at times quite plausible for the reason that rainfall is variable, both as to the amount of precipitation at any one time and as to its continuation during an important period of the cropping season. Ditches work no injury during the time they are not needed, but are a necessity at other times, their value at such times being measured by their ability to receive the surplus water necessary to save the land and crops from injury.

It is convenient to consider the volume of water to be removed by drains in twenty-four hours at a certain depth expressed in fractions of an inch over the entire area. This is represented in computations by cubic feet per second which will be required to remove the unit of depth from 1 square mile or 1 acre in twenty-four hours. This unit of drainage run-off is not the same for all parts of a watershed but is greater for small areas than larger ones and for the upper part of a drainage basin than for the lower. It must be determined by comparing the conditions prevailing in areas which have been successfully drained with those in the area for which it is desired to fix a unit.

After comparing the requirements of this valley with those of other areas, taking into consideration the rainfall, climate, and topography of the region, the unit fixed upon for computing the required capacity of main drains is one-quarter inch in depth for the drainage outlet of 25 square miles or 16,000 acres, increasing for smaller areas and decreasing for larger ones in the ratio given in the following table:

Drainage coefficients used in computing size of ditches.

Square miles.	Acres.	Amount of water to be removed per acre per second = C.	Square miles.	Acres.	Amount of water to be removed per acre per second = C.	Square miles.	Acres.	Amount of water to be removed per acre per second = C.
		Cubic feet.			*Cubic feet.*			*Cubic feet.*
4	2,560	0.0210	22	14,080	....	75	48,000	0.0092
5	3,200	....	23	14,720	....	100	64,000	.0090
6	3,840	.0184	24	15,360	....	108	69,120	....
7	4,480	....	25	16,000	0.0105	144	92,160	....
8	5,120	.0175	26	16,640	....	180	115,200	....
9	5,760	....	27	17,280	....	200	128,000	.0080
10	6,400	.0157	28	17,920	....	216	138,240	....
11	7,040	....	29	18,560	....	252	161,280	....
12	7,680	....	30	19,200	.0104	288	184,320	....
13	8,320	....	31	19,840	....	300	192,000	.0076
14	8,960	....	32	20,480	....	324	207,360	....
15	9,600	.0131	33	21,120	....	360	230,400	....
16	10,240	....	34	21,760	....	400	256,000	.0073
17	10,880	....	35	22,400	....	500	320,000	.0071
18	11,520	....	36	33,040	....	600	384,000	.0070
19	12,160	....	40	25,600	.0100	800	512,000	.0069
20	12,800	.0120	50	32,000	.0097	1,000	640,000	.0064
21	13,440	....	72	46,080	....			

This table expresses the discharge in cubic feet per second per acre to be used in determining the capacity of ditches required for the several areas opposite them. Figure 1 shows these quantities platted

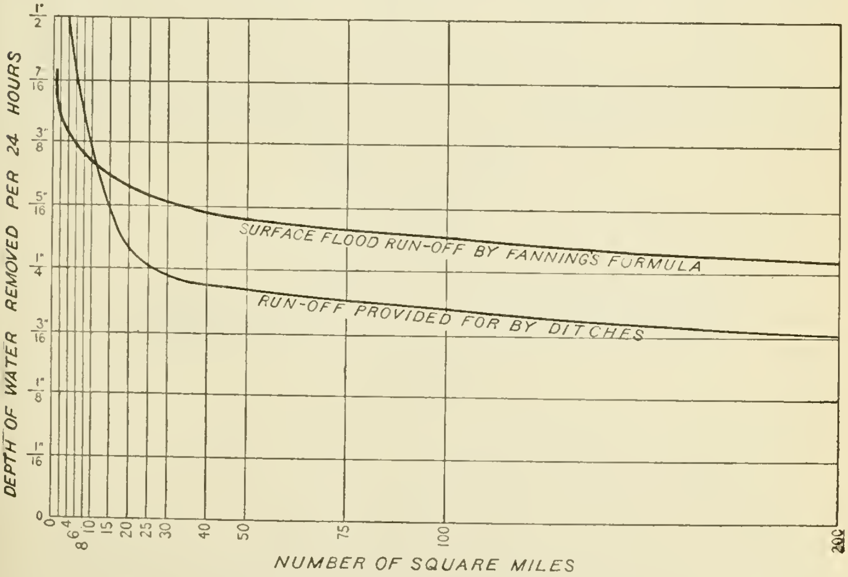

FIG. 1.—Curves showing relation between flooded areas and depth of water to be removed in Red River Valley, North Dakota.

so as to represent the law of flow graphically. The coefficients given in the table which follows express the flood run-off of the valley on the

Minnesota side as estimated by Mr. J. T. Fanning in 1886. They are computed by the formula

$$\frac{12\,M^{\frac{9}{10}}}{C=640\,M}$$

in which

C = cubic feet per second.
M = square miles of drained area.

Volume of flood run-off in Red River Valley, estimated by J. T. Fanning.

Area in square miles.	Approximate flood flow per second per acre.	Area in square miles.	Approximate flood flow per second per acre.	Area in square miles.	Approximate flood flow per second per acre.	Area in square miles.	Approximate flood flow per second per acre.
Miles.	*Cubic foot.*	*Miles.*	*Cubic foot.*	*Miles.*	*Cubic foot.*	*Miles.*	*Cubic foot.*
1	0.0188	10	0.0149	50	0.0127	500	0.0101
2	.0175	15	.0143	75	.0122	600	.0010
3	.0168	20	.0139	100	.0120	800	.00099
4	.0163	25	.0136	200	.0110	1,000	.00094
6	.0157	30	.0133	300	.0106		
8	.0152	40	.0130	400	.0103		

The second curve in figure 1 is platted from the coefficients given and is here presented to show graphically the law of flow and run-off under the different conditions of drainage.

The following formula has been used in determining and proportioning the size of the ditches for areas of 1,000 acres and over. For areas less than 1,000 acres the size of ditch is not increased, since experience has shown that it is not practical to use a smaller one in this land, considering its first cost and that of subsequent maintenance. The formula is applicable to ditches in good condition and within the limits of size of those required in this territory.

$$Q=a\sqrt{\frac{a}{p}\times 1\tfrac{1}{2}f}$$

in which

Q = discharge in cubic feet per second,
a = area of cross-section of waterway,
p = wet perimeter,
f = fall in feet per mile.

$$A=\frac{Q}{C}$$

in which

A = number of acres drained.
C = coefficient from table on page 23.

A trial size of ditch at a certain point should be assumed, in which the water at ordinary flood stage may flow at a certain height without injury to adjoining land and the value of Q found by the formula. This value divided by C for the estimated watershed area will give the value of A, or the number of acres which the assumed ditch will serve. The change in character of watershed and the entrance of tributary streams should be considered in connection with the use of the formula in fixing the size at various points. This formula judiciously used will be found useful to engineers and others in modifying the size of ditches recommended in this report or in designing other systems so that the relation of tributary to main ditch systems may be maintained. A caution should be given in this connection. The tendency of drainage boards is to make the size of ditches for the larger areas too small for the work required of them at times of greatest need. It should be remembered that the saving of a single crop will pay several times over the additional cost of a drain with capacity sufficient to reduce the risk of injury from this source to a minimum.

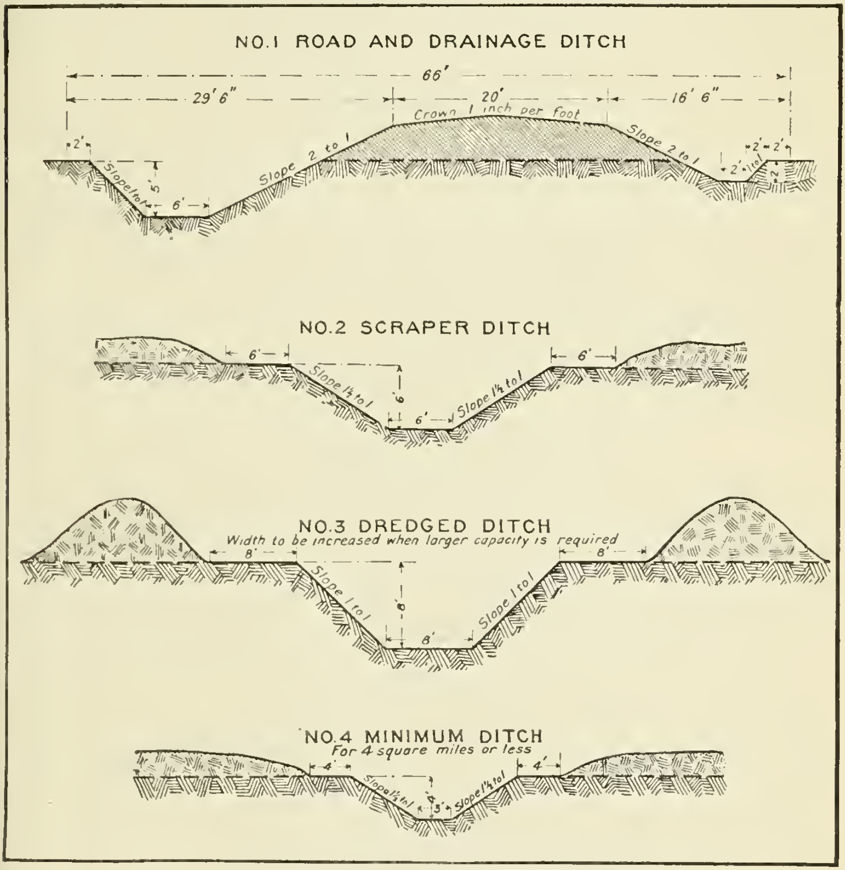

FIG. 2.—Cross sections of ditches recommended.

FORMS OF DITCHES.

The crumbling nature of exposed soil occasioned by the action of the frost requires side slopes of ordinary ditches to be not steeper than 1 to 1 if reasonable permanence is to be expected. Ditches wider than 6 feet on the bottom may have steeper slope, but it may be expected that the earth on the sides will crumble and fall and reduce the bottom width to 4 feet unless there is sufficient scouring action of the stream to remove the earth. In either case the section of the ditch will be considerably modified. The methods of construction found necessary or desirable in practice often govern in this matter, but observation and practice so far in the valley sustain the opinion that slopes 1 to 1 or 1½ to 1 are preferable in this soil and climate where the ditches have a bottom width of 6 feet or less and are more than 3 feet deep. Roadside ditches whose excavation is used for making a road embankment may have a steep slope on the land side and a 2 to 1 slope on the road side (fig. 2). Such a ditch bank can be readily mowed with a machine and the bottom cleaned with drag scrapers. Ditches with flat slopes need have no berms, but those with 1 to 1 and 1½ to 1 slopes should have berms 6 feet wide where the ground is firm and 8 feet wide where it is soft and unstable (fig. 2, Nos. 1 and 2).

Experience in this work teaches that it is impracticable to make ditches with teams and scrapers through wet and marshy land. Some type of steam land dredge should be used.

The tabulated estimates arranged to accompany the maps specify the size and side slopes of the ditches recommended for the several lines and are designed to meet the several local conditions.

EROSION OF CHANNELS.

The ditches of the valley are easily eroded where the fall is 4 feet or more per mile, especially if they run full at maximum flow. Erosion is mathematically stated to vary as the square of velocity. Since velocity varies as the square root of fall for any given distance, the tendency to erosion increases in proportion to the fall or per cent of grade, a fall of 6 feet per mile producing twice the erosion of a grade of 3 feet per mile, other conditions being equal. This is only an expression of the comparative wearing action of water upon the channel. The cutting action of a stream depends more largely upon the structure of the soil through which it passes than upon its velocity of flow.

The following precautions taken in the construction of ditches will greatly assist in preventing washes which when started are difficult to control. Ditches discharging into a coulée, river, or other outlet should do so without an overfall or abrupt drop, since a drop causes a continual sloughing off and cutting back of the channel. They should discharge into the receiving channel at the usual water line of the latter if possible, the drop being taken up by means of a gradual slope. Much silting of ditches and natural streams at junction points can be prevented by observing this precaution. The channel should not be enlarged at some points and suddenly contracted at others. Where there is a tendency to wash, the velocity of flow may be decreased and the cutting process checked by gradually widening the ditch so that the water will flow at a less depth where the cutting occurs. This is in direct opposition to the requirements of the channel for carrying the volume of water coming to it, and for that reason is not often done, but many big washes at the discharging points of drainage ditches and water courses could be prevented by the method suggested, if taken in time. More attention should be given to the matter at the time ditches are constructed, especially where the soil and under-clay is characterized by vertical cleavage.

SILTING OF DITCHES.

Ditches in this as well as other valleys having a similar soil are not infrequently obstructed by bars of soil blown into them by the wind. The top 6 inches of soil becomes finely divided by exposure to the weather and being light (the top soil weighing only 47 pounds to the cubic foot when fully dry) is carried from the summer-fallowed and fall-plowed fields at various exposed points. Where this occurs a strip of land a rod or more wide on each side should be maintained in grass. This plan is found quite effective in Iowa and Illinois, where similar difficulties are experienced. A perfect grading of the bottom of the ditch also lessens the deposit of silt.

Ditches should receive timely care. Weeds and grass should be removed from them every fall, and small bars or other obstructions taken out when the cost is but a trifle. Systematized supervision is essential to their economical maintenance as well as their efficiency, and should be provided for in the organization and management of drainage districts.

EFFECT OF STRAIGHTENING NATURAL DRAINAGE CHANNELS.

The natural channels of the valley may be improved for drainage purposes by removing obstructions from the bottom and sides, so that the least possible resistance will be offered to the flow, and by cutting bends where practicable, by which means the distance of flow may in some cases be shortened to one-half or one-fourth of that of the original stream. A stream may often be improved by both methods. In any event, the first should be employed, since the discharge of a ditch or natural stream may be increased considerably by removing brush, drift, and other obstructions, and smoothing the sides so that they will offer little frictional resistance. The advantage of a clean and well-kept earth channel over one obstructed by brush, earth projections, and a general irregular section appears in the experiments made to determine the value of n, the coefficient of roughness used in

Kutter's formula for velocity. For ditches in good condition it was found that n should be given a value of 0.022, while for channels in very bad condition a value of 0.035 should be used. A ditch 10 feet wide, side slopes 1 to 1, with water flowing 2 feet deep on a grade of 8 feet to the mile, has a flow of 3.32 feet per second and a discharge of 79.68 cubic feet per second, when $n=0.022$. When $n=0.035$, we have a velocity of 2.05 per second and discharge of 49.2 cubic feet per second, giving a difference of 60 per cent in favor of the clean channel. The advantage gained by cutting abrupt bends is, first, that arising from the additional fall given, which is in proportion to the shortening of the channel. Shortening the length to one-half the original doubles the head or grade, and shortening to one-fourth the original gives four times the fall between the points improved. Since the velocity of flow increases as the square root of the head, the increased velocity due to shortening the channel would be 40 per cent in the first instance and twice the original velocity in the second, provided the channels in the two cases were equal in section and roughness. Another advantage from the straightening of the channel is the lessening of friction to flow occasioned by bends. The amount of resistance offered by bends is dependent upon their sharpness. Where it is practicable to straighten crooked channels, the increase of velocity secured by cutting bends may be fully 10 per cent, provided the cut-off channel has a cross section equal to the original. The precise amount of this gain, except that due to increase of head, has not been satisfactorily determined, but nevertheless exists and is recognized in practical work. As a general proposition it may be observed that reducing the length of an ordinary drainage channel one-half by cut-offs will increase the velocity of flow 40 per cent due to increased head, 5 to 10 per cent due to removal of friction caused by bends, and 40 to 50 per cent due to betterment of channel by reducing the coefficient of roughness, the improvement approximately doubling the carrying capacity of the stream. When such an improvement is made it should be remembered that if the channel below the cut-off does not have the capacity to receive the increased volume, overflow will result and the benefit secured for land above the improvement will be offset by injury from overflow farther down the stream. Such improvements wherever begun should be carried downstream to a point where the channel has ample capacity to receive the increased volume of water.

The natural streams of the valley may be effectively improved by removing obstructions from the bottom and sides of the channels, trimming them so that the cross section will be uniform, and cutting the sharp points from the bends. From the preceding discussion it will appear that in this way their carrying capacity may be increased without expensive cutting of bends. The plans for drainage contemplate the use of coulées as ditches. They are by no means ideal channels for this purpose, but because of their availability and ample capacity we can not afford to disregard them. They are usually uneven in section and not well graded on the bottom. These conditions may be bettered without great expense, and when connected with an outlet stream the coulée becomes a good drainage channel.

METHOD OF MAKING THE SURVEY.

To properly design a system of drainage requires a knowledge of the nature of the streams and the general surface slope. The maps and reports of previous surveys made in the valley show with sufficient accuracy the location of the roads, streams, and improvements; but as there were no data relating to elevations, it was necessary to make a level survey. All available data from various sources, such as the county and United States Geological Survey maps, were compiled on United States Land Office township maps, on a scale of 2 inches to the mile. These maps were used during the progress of the work as field sheets. A reconnaissance showed that levels necessary to determine the surface slopes and the fall of streams could be obtained by running along the section lines. As these lines are all plainly marked by roads, fences, or turning rows, and the greater part of the quarter lines were visible, the level work could be carried on without field measurements other than pacing.

A party suitably equipped for the survey was assembled at Fargo and field work begun on June 20 in the southeastern part of Cass County. The outfit consisted of four level parties, each consisting of a levelman and rodman. To avoid the loss of time in looking up boarding places and to hold the corps in close touch with each other and the work, arrangements were made for field subsistence. The subsistence part of the outfit consisted of a cook and teamster and the necessary teams and camp equipment. Supplies were bought as needed from farmers or in small towns along the line of work. Camp was moved every other day a distance of 12 to 15 miles. While the four parties worked independently of each other, they were boarded in one camp and were under the general direction of the levelman. The method of procedure was to have breakfast at 6 a. m., immediately after which the level parties set out for their respective lines, either afoot or in the light wagon, each man carrying his lunch in a small canvas bag.

As the day's work for all started at a given point, each party had the same number of miles to run. Each party as it arrived at the designated line took up the work and carried it forward to a point of closing, taking such time for lunch as they desired, returning to camp on reaching the closing point. Four lines were thus carried in one direction simultaneously. A distance of 7 to 10 miles per day was completed by each party. Each evening the notes were platted on the field sheets and the campmen and levelmen received instructions for the following day from the levelman in charge. Four lines were carried west and for the purpose of checking were connected at the western side of the area surveyed and a line run far enough north to give the starting-points from which four lines were carried east to the river. Along the most practicable route near the river the base line was extended north by a duplicate line of levels, temporary benchmarks being set at each section line, the elevation of each being the average of the elevations as determined by the two lines of levels. The benchmarks on this base line were the points from which the elevations on the east and west lines were started and closed. Elevations were taken each quarter of a mile, care being taken to drive the turning pin where the surface had not been disturbed by grading or excavating. Equal sights of 660 feet each were taken, the target being set and read by both levelman and rodman. Temporary benchmarks were usually set at section corners. These benchmarks were made by driving 60-penny spikes horizontally into posts or the ends of culverts and were marked by blazes, the level rod being held on the head of the spike.

The survey of Pembina County was begun on June 29, 1906, and completed August 15 following. The plan of carrying on the survey was the same as that used in surveying Cass, Traill, Grand Forks, and Walsh counties during the previous year, except that eight lines were run at one passage, instead of four. This plan obviated the necessity of moving camp every day. Four lines were run ahead for one day, the men being brought back to camp by the team, and on the following day the four lines next north were run, the camp moving on that day to a point where the men would close the day's work. These four lines were then carried on 8 miles the next day, camp remaining in the same location. On the following day the south four lines were carried ahead, the camp moving on that day, and in this manner the work progressed across the country in sections of 8 miles in width in place of 4 miles as was done the previous season.

The datum for the elevations is a United States Geological Survey bench mark, the elevation above sea level being based on the benchmark set by the United States Coast and Geodetic Survey at Wahpeton, N. Dak. With this as an initial benchmark, the base line was started and was carried to the north limit of the area surveyed by a duplicate line of levels. The following permanent benchmarks, each checked by a second line, were set:

Benchmarks established in Red River Valley.

Location.	Description.	Elevation.
		Feet.
Datum	Benchmark at Enloe in the northeastern part of Richland County, N. Dak., and described by the U. S. Geological Survey as follows: Sperry, T. 135 N., R. 48 W., sec. 20, north side of; south of railroad crossing, west side of Chicago, Milwaukee and St. Paul Railway track, 20 feet south of section line, iron post stamped "934 W," elevation.	934.612
Fargo	In the court-house yard, north U. S. Geological Survey meridian mark.	904.01
Do	In court-house yard, south U. S. Geological Survey meridian mark.	904.19
Do	Agricultural college administration building, lowest section of red sandstone coping, on west balustrade at main entrance. Benchmark is 6.4 feet below doorsill and 2.6 feet above surface of ground. Cross cut in center of coping.	904.45
Do	Red River gauge at Front street bridge. Zero of gauge	863.14
Haggart	Sheyenne River gauge at Haggart's private bridge. Zero of gauge.	880.92
Hillsboro	Public school building. Red sandstone window sill near northeast corner, on north side of building. Benchmark level with the surface of the ground and 5.4 feet below the red sandstone water table at the main floor. Cross cut in sill.	904.61
Do	County jail, west end of limestone doorsill at main entrance, cross-cut sill.	910.46
Grand Forks	Public school yard, north U. S. Geological Survey meridian mark.	832.85
Do	Public school yard, south U. S. Geological Survey meridian mark.	833.27
Do	University of North Dakota, Science Hall, northeast corner of square base under round base of north column at main entrance. Benchmark is about 4½ feet above surface of ground.	840.71
Do	Red River gauge on Northern Pacific Railroad bridge. Zero of gauge.	781.43
Grafton	Court-house main entrance, top of limestone flag, south side of center pier, front edge of stone. Cross cut in stone.	834.97
Do	Carnegie Library, west side of main entrance, southwest corner of stone base on which lamp-post stands, 2.6 feet above surface of ground, 1.1 feet below doorsill.	835.76
Pembina	West bank Pembina River north of road leading to ferry, in yard of Sheriff Atkinson, U. S. Geological Survey iron benchmark post.	793.18
International boundary	Top of first boundary post west of Red River, 400 feet west of Northern Pacific Railway tracks.	797.07
Emerson, Manitoba	Red River gauge on Emerson Bridge. Zero of gauge	739.90

Where benchmarks are not available, elevations with sufficient accuracy to begin surveys can usually be had by taking the elevation of the natural surface of the ground at several points along an east and west line where there are recorded elevations as shown by the plat.

CHARACTERISTICS OF STREAMS TRIBUTARY TO RED RIVER.

The first tributaries of any importance that enter the Red River from the west are the Wild Rice and the Sheyenne rivers. Both rivers have deep-cut channels through the lacustrine deposits and for a number of miles flow a short distance west of and parallel to the river.

The Sheyenne River rises near the center of North Dakota and, as shown upon the map (Pl. I), has a large drainage basin. At several points below Hardwood slides have occurred which have greatly diminished the capacity of the channel. The Maple River, where it enters the area surveyed, is a sluggish stream with a high bank on the east side, the west bank being somewhat lower. After passing Mapleton the channel grows deeper and narrower, with banks of equal height. The Rush River is a small stream the channel of which gradually disappears by discharging its waters over the surface of the surrounding land. The Elm River and its south branch are deep, clean channels of good capacity. The north branch below Kelso and above the Hillsboro Beach has a narrow, shallow, and crooked channel, badly obstructed by growing bushes. The Goose River east of Hillsboro has a deep channel, but west of Hillsboro it meanders back and forth over a narrow valley.

In Grand Forks and Walsh counties there are several basins and valleys lying below the general surface. At times of high water they become large lakes, but during the low-water period they are marshes and swamps. Lands comprising these basins are frequently strongly impregnated with alkali, and in some instances saline springs prevent the deeper parts of the basins and channels from becoming fully dry. The Turtle, Forest, and South, Middle, and North forks of Park River are small, tortuous streams, flowing through narrow channels fringed on either side by a thick growth of timber. The channels of these streams are not sufficiently large to carry the flood waters near the west line of the area surveyed, but do serious injury by overflowing the land adjacent to them. These channels, however, are of ample size to carry the water after they have traversed the flat area for a distance of 5 or 6 miles.

Lying parallel to and 6 miles west of the Red River, in Pembina County, is a low depression which extends from near the Walsh County line to the Tongue River. It has no discharge outlet to the east, practically no fall toward the north and, receiving the drainage from a large area to the west, forms the largest swamp of the entire section surveyed. Several ditches have been cut for the purpose of draining this slough, so that though not thoroughly drained it occupies a much smaller area than formerly. The Tongue River is a crooked, narrow stream having a channel of varying size, with numerous low places in its banks, and overflows at various points between the foothills and its place of discharge. Probably more damage is caused by the overflow of this stream than any other tributary river in the valley. The Pembina River is the largest stream north of the Sheyenne on the Dakota side. While it is crooked and its banks are thickly wooded, it has a good channel which, under ordinary conditions, carries the flood of its watershed. There are a few places along its banks where overflows occur that have done considerable damage, and it is suggested that low levees be constructed at such points. Overflows from both the Tongue and Pembina rivers have occurred after seeding time and are independent of the Red River flood.

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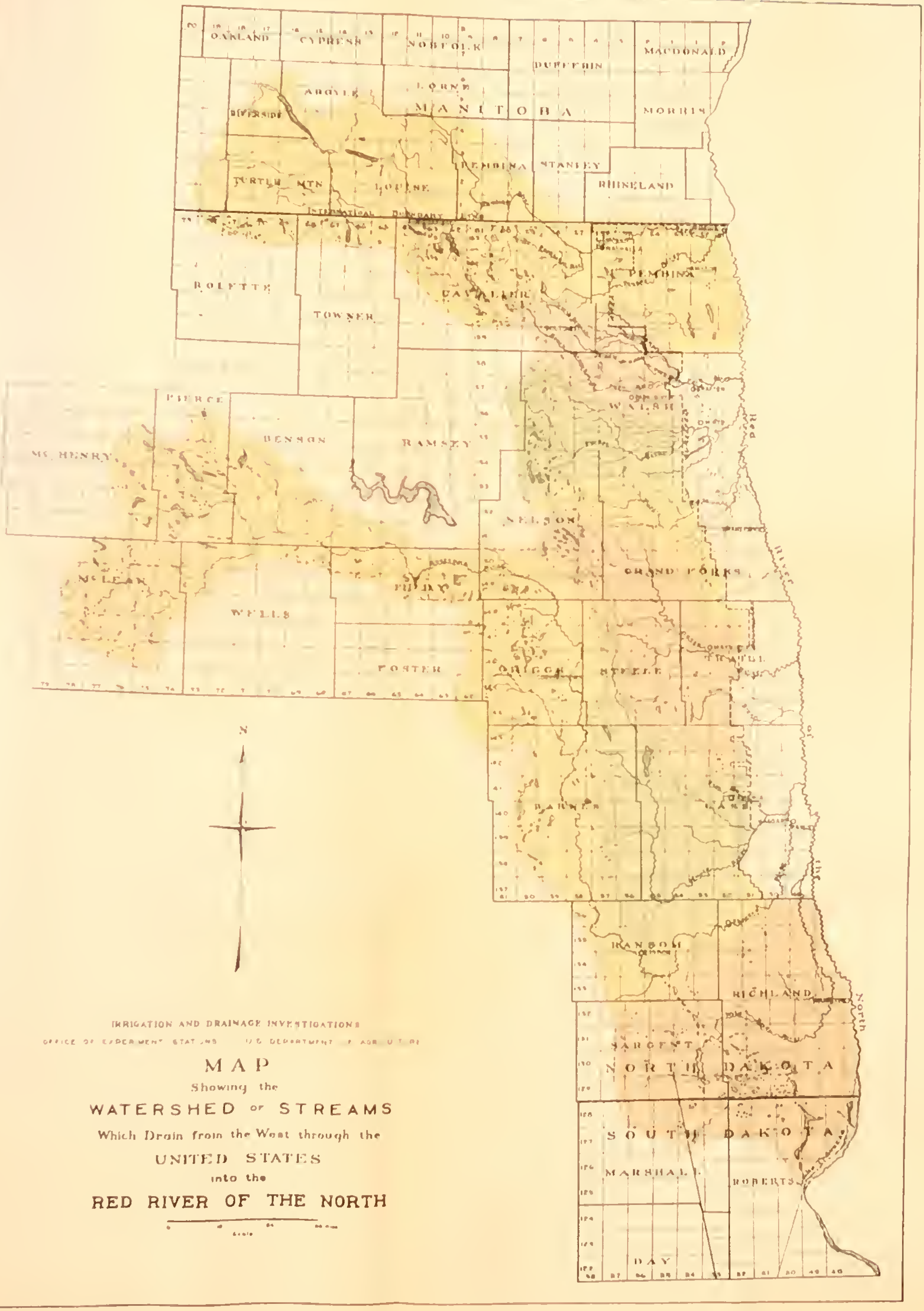


IRRIGATION AND DRAINAGE INVESTIGATIONS

OFFICE OF EXPERIMENT STATIONS U. S. DEPARTMENT OF AGRICULTURE

MAP
Showing the
WATERSHED OF STREAMS
Which Drain from the West through the
UNITED STATES
into the
RED RIVER OF THE NORTH

Scale

Problems relating to the Red River have not been taken up in this report. That stream is the natural outlet for the waters of the valley and is under Federal control. The drains have been designed to collect surplus waters of the valley and discharge them into the river for the benefit of the lands used for agriculture. The solution of the river problem is dependent upon a greater number of factors than we now have at hand. The drainage herein recommended is a work that will yield immediate returns. No construction of reservoirs on tributary streams nor improvement of the Red River will render such drainage unnecessary or materially change the general plans herein recommended. Furthermore, it is a work which lies wholly within the power of the owners of the land concerned to inaugurate, direct, and complete for their own benefit.

The following table shows the drainage areas of streams which discharge into the Red River from the west. Unless otherwise stated, the area given is the area down to the west limit of the surveys:

Drainage areas of tributaries of Red River.

Name of watershed.	Square miles.	Name of watershed.	Square miles.
Bois Des Sioux in South Dakota	254	Ojata district, Main A	25
Bois Des Sioux in North Dakota	252	Ojata district, Hazen Creek	31
Wild Rice, at South line of Cass County	2,060	Turtle River	330
Sheyenne River	5,200	Turtle River district, Main C	30
Canfield district, Main A, west of survey	8	Turtle River district, Main B	15
Canfield district, Main B, west and south of survey	23	Turtle River district, Main A	2
Maple River	1,350	Turtle River district, main coulee	40
Rush River at Amenia	260	Forest River	645
Hunter district, Main B	6	Grafton district, Main D	32
Hunter district, Main A	27	Grafton district, Main C	40
Elm River south of Traill County line of survey	78	Grafton district, Main B	28
Elm River, middle branch	116	South Fork of Park River	254
Elm River, north branch	83	Middle Fork of Park River	118
Goose River	1,100	North Fork of Park River	272
Coven Creek	36	Tongue River at West Line of range 54	200
Thompson district, Main C	36	Little Pembina River, at mouth	340
Merrifield district, lateral No. 15	5	Pembina River, at junction with Little Pembina	2,750
Merrifield district, lateral No. 14	5	Pembina River, at west line of range 54	3,225
Ojata district, Salt Coulée	21	West watershed of Red River at international boundary	18,900

Areas surveyed.

County.	Miles of main line.	Miles of check line.	Square miles surveyed.	Days worked.	Days lost.
Cass	656.6	153.0	645.0	116.8	31.2
Traill	449.6	108.9	450.0	71.8	16.2
Grand Forks	555.0	138.0	560.0	87.5	20.0
Walsh	408.6	83.3	380.0	62.4	4.1
Pembina	942.0	120.0	950.0	142.0	19.0
Total	3,011.8	603.2	2,985.0	480.5	90.5

ESTIMATES.

Estimates have been made at what is thought to be fair prices for the work, yet the continued advance in prices of material and labor and the varying conditions which may prevail at the time the work is done make it difficult to estimate the cost of the work far in advance of the time of its construction. The figures here given represent the comparative cost of the different classes of work at the prices named. Unless otherwise mentioned, the territory lying outside of the area surveyed is not included in computing the size of drainage districts.

Main drainage channels near the west boundary of the area surveyed are designed to carry the water coming to them from the natural watershed on the west. Unless otherwise specified, all main ditches are designed with a slope of 1 to 1, and lateral ditches with a slope of 1½ to 1 on either side. Where ditches are located along the highways, a slope of 1 to 1 on the land side and 2 to 1 on the road side is recommended. The grade of the ditch is not given when its size is not dependent upon it.

Estimates for bridges are made for temporary timber structures on the supposition that the county and township will substitute permanent ones later. The width of right of way used in the estimate is the average width for the specified length of the ditch. The prices used are 10 cents per cubic yard for ditches when constructed by steam machinery, and 11, 11½, and 12 cents for other ditches, as indicated in the following table showing the cost of ditches of different sections and depths. It may be found advisable in some cases to change the location in order to meet local objections or to serve interests not considered in the general plan of drainage which is outlined in this report. Specific examinations should be made by the district engineers, especially with regard to the improvement of coulées and the outlets of ditches which discharge into them. These local conditions, and especially the facilities for doing the work, may result in the modification of the estimated prices here given.

COST OF EXCAVATION.

The cost of excavation given in the following table is for ditches of varying depth and bottom width, with a slope of 1½ to 1 on either side, or its equivalent 1 to 1 on the one side and a 2 to 1 slope on the other:

Cost of excavation.

Bottom width.	Average depth 4 feet, cost 11 cents per cubic yard.			Average depth 5 feet, cost 11½ cents per cubic yard.		
	Cubic yards in 100 feet length.	Cost of 100 feet length.	Cost of 1 mile.	Cubic yards in 100 feet length.	Cost of 100 feet length.	Cost of 1 mile.
3	133	$14.63	$772.45	194	$22.31	$1,177.97
4	148	16.28	859.38	213	24.30	1,293.60
5	163	17.93	846.70	232	26.68	1,408.70
6	178	19.58	1,031.92	250	28.75	1,518.00
7	193	21.23	1,120.94	268	30,82	1,627.30
8	207	22.77	1,202.25	287	33.00	1,742.40
10	237	26.07	1,376.48	324	37.26	1,967.33

Cost of excavation—Continued.

Bottom width.	Average depth 6 feet, cost 12 cents per cubic yard.			Average depth 7 feet, cost 12 cents per cubic yard.		
	Cubic yards in 100 feet length.	Cost of 100 feet length.	Cost of 1 mile.	Cubic yards in 100 feet length.	Cost of 100 feet length.	Cost of 1 mile.
3	267	$32.04	$1,691.71	350	$42 00	$2,217.60
4	289	34.68	1,831.10	376	45 12	2,382.34
5	311	37.32	1,970.50	402	48 24	2,547.07
6	333	39.96	2,109.71	429	51.48	2,698.14
7	356	42 72	2,255.62	454	54 48	2,876.54
8	378	45 36	2,395.00	480	57.60	3,041.28
10	422	50 64	2,673.79	532	63.84	3,370 75

RECOMMENDATIONS.

As will be seen from the foregoing discussion, the efficiency of existing natural watercourses can be increased by improving the channels where they are subject to overflow, since any obstruction in a stream causes an accumulation of sediment which greatly injures the efficiency of the channel. Low bridges, dams, or piling which in any way cause an obstruction or catch drift, and also timber and brush growing upon the banks above the ordinary high-water line, should be removed. This will secure a good flow and permit the channel to enlarge by erosion during the high-water period instead of being made smaller by the accumulation of drift and sediment, as is now the case. Where bridges across channels are necessary, piling or piers should not be placed in the center of the channel, but near the banks.

If the timber is removed from the banks so as to permit the free access of sun and air during the thawing period of the spring, the snow and ice will be removed from the channel more quickly, thus obviating much of the injury which occurs from the forming of ice jams during the early spring season. While timber and brush growing at a distance from the banks will frequently prevent the snow from drifting and filling the channel, the same growth on the slopes and near the banks will prevent the uniform thawing of the snow and ice when the channel should be open.

There are points along the banks of the streams which are low, subjecting the outlying lands to periodical overflow. A low levee constructed along the banks at those places will in many cases prevent the injury. In some localities bends may be cut off to advantage, but considerable care and judgment should be used when this is done. While it is true that the velocity of flow can be greatly increased by straightening the channel of a stream, care should be taken to determine whether the channel which is to receive the water from the cut-off has sufficient capacity to carry the additional flow occasioned by the construction of the cut-off channel. Where banks of streams are higher than the land a short distance away from them, as is true of nearly all of the streams in the valley, they act as natural levees to hold the streams within their channels, and should not be cut to furnish an outlet for a drainage ditch unless it is impossible to secure such outlet in any other way. There are usually coulées and natural channels running parallel to the streams, back of the bank ridge, which finally enter the main stream, into which ditches may be discharged. Wherever it is possible all ditches should enter the streams through these natural channels. It would greatly facilitate drainage movements in the area surveyed if tributary streams were declared drainage channels and placed under the supervision of drainage authorities.

ACKNOWLEDGMENTS.

In the preparation of this report the engineer in charge wishes to acknowledge information furnished by bulletins and officers of the North Dakota Agricultural College; by reports and the section director of the U. S. Weather Bureau in North Dakota; by reports and the resident hydrographer of the U. S. Geological Survey; and by the Corps of Engineers of the United States Army.

FINANCIAL STATEMENT.

The cost of entire work to each of the cooperating parties was as follows:

Cass County, field work	$750.00
Traill County, field work	532.04
Grand Forks County, field work	663.83
Walsh County, field work	407.43
Pembina County, field work	550.00
State engineer's office, field work—Cass, Traill, Grand Forks, and Walsh counties	565.00
State engineer's office, mapping	525.00
State engineer's office, field work, Pembina County	237.40
Great Northern Railway, Pembina County	900.00
Irrigation and drainage investigations, field work	1,854.29
Engineer in charge, plans and estimates on field	875.00
Incidentals	195.00
Preparation of report, maps, etc., Washington	1,150.00
Cost of engraving maps and printing report (estimated)	1,500.00
Total	10,704.99

DETAILED ESTIMATES FOR SEPARATE COUNTIES.

CASS COUNTY.

(See map, Pl. II.)

Since the Sheyenne and Wild Rice rivers are subject to overflow, no more ditches than are necessary are designed to outlet into these streams. The object in carrying the drainage parallel to the streams is to prevent the cutting of the ridges which border the river channels on either side. Low places in the banks can be raised and the carrying capacity of these streams greatly increased at a small expenditure.

HICKSON DISTRICT.

Hickson district covers an area of 12,800 acres, lying between the Wild Rice and the Red rivers. Drainage from Richland County should be carried south of the county line road and enter the Red River through the coulée which crosses the county line near the Red River. Main A drains 9,000 acres at the mouth, side slope 1½ to 1.

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	4.50	7.0	1.0	6.0	356	$2,256	$10,152
	1.00	6.0	1.0	6.0	333	2,110	2,110
	2.00	3.0	2.0	5.0	194	1,178	2,356
	2.00	3.0	2.0	4.0	133	772	1,544
Lateral	4.00	3.0	2.0	4.0	133	772	3,088

Right of way 7.5 miles in length, 33 feet wide, Main A, 30 acres, at $30 per acre.	$900
Six highway bridges, Main A, 150 feet, at $6 per foot	900
Contingencies, Main A	1,300
Cleaning out coulée in section 14, Pleasant Township, laterals	860
Contingencies, laterals	300
Total cost for district:	
Main A	19,262
Laterals	4,248
Total	23,510
Average cost per acre	1.84

THE ROSE COULÉE DISTRICT.

The Rose Coulée district covers an area of 39,000 acres lying east of the Sheyenne River. Main A drains 16,000 acres at the mouth, side slope 1 to 1; Main B drains 7,000 acres at the mouth, side slope 1½ to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	1.00	3.0	1.0	4.0	No. 11	1.50	3.0	1.0	5.0
No. 2	1.00	3.0	....	4.0	No. 12	1.50	3.0	1.0	4.0
No. 3	1.75	3.0	....	5.0	No. 13	1.00	3.0	1.0	5.0
No. 4	1.25	3.0	....	5.0	No. 14	1.00	3.0	1.0	5.0
No. 5	.75	3.0	....	4.0	No. 15	1.00	3.0	1.0	5.0
No. 6	1.75	3.0	1.0	4.0	No. 16	3.25	3.0	2.5	4.0
No. 7	.75	3.0	....	4.0	No. 17	2.00	3.0	....	4.0
No. 8	1.50	3.0	1.0	5.0	No. 18	.75	3.0	....	5.0
No. 9	1.00	3.0	....	5.0		1.00	3.0	....	4.0
	3.00	3.0	....	4.0	No. 19	2.50	3.0	....	4.0
No. 10	1.50	3.0	1.0	5.0					

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	3.75	8.0	1.0	7-10	567	$2,995	$11,231
	3.00	7.0	1.0	7.0	363	1,917	5,751
	2.00	6.0	1.0	6.0	267	1,410	2,820
	1.00	3.0	....	6.0	200	1,056	1,056
	.75	3.0	....	5.0	148	781	586
	1.25	4.0	1.0	5.0	167	882	1,102
Main B	2.25	5.0	1.6	6.0	311	1,970	4,432
	2.00	3.0	2.0	5.0	194	1,178	2,356
Laterals	18.50	3.0	....	4.0	133	772	14,282
	12.25	3.0	....	5.0	194	1,178	14,430

Right of way 9 miles in length, 33 feet wide, Main A, 36 acres, at $30 per acre	$1,080
Seven highway bridges, Main A, 150 feet, at $5 per foot	750
Contingencies, Main A	2,000
Cleaning out 1.75 miles of coulée in sections 11 and 12, Stanley Township, Main B	1,500
Contingencies, Main B	600
Contingencies, laterals	2,900
Total cost for district:	
Main A	26,376
Main B	8,888
Laterals	31,612
Total	66,876
Average cost per acre	1.71

FARGO DISTRICT.

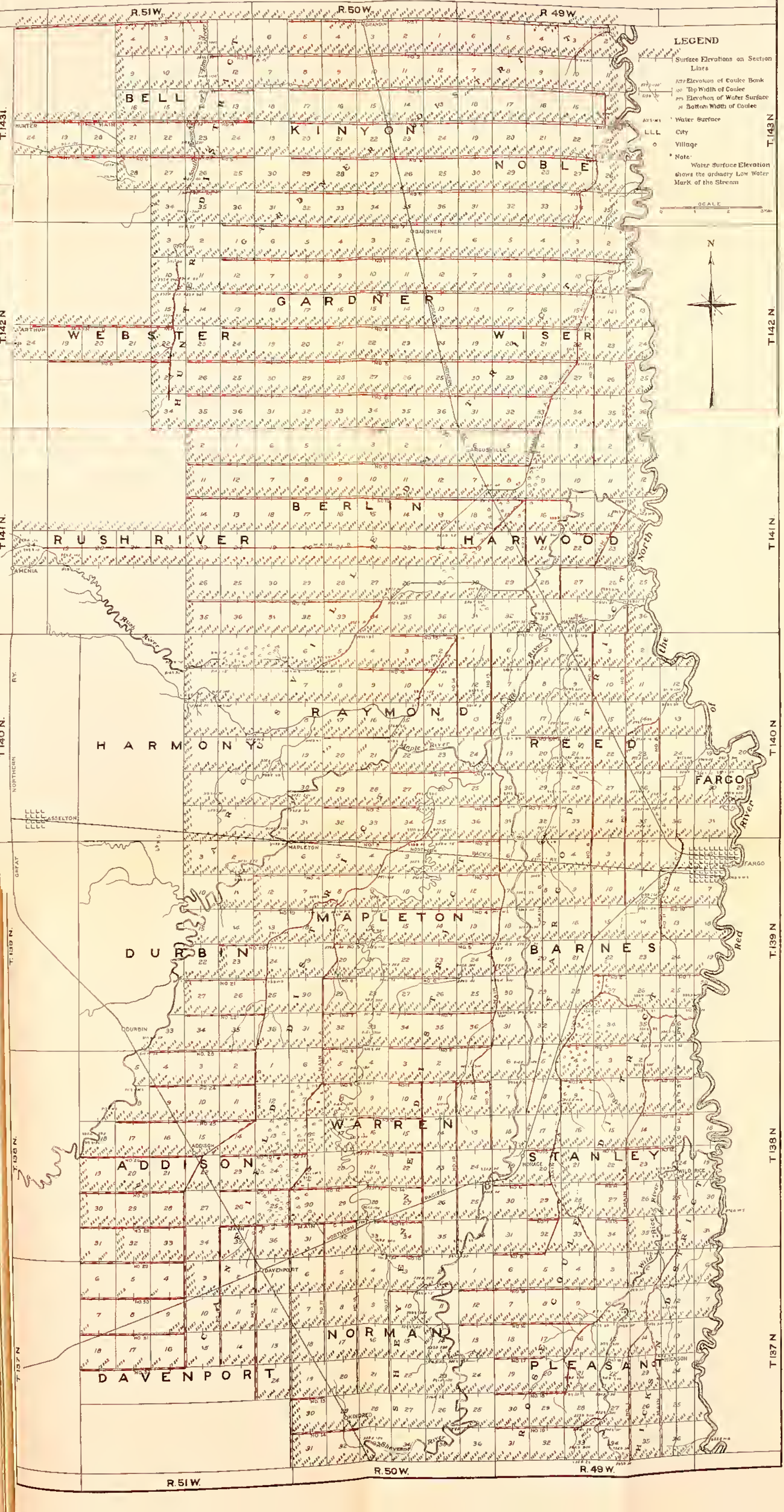
The Fargo district covers an area of 35,000 acres lying east of the Sheyenne River. Main A drains 4,000 acres at mouth, side slope 1½ to 1; Main B drains 7,300 acres at mouth, side slope 1½ to 1; Main C drains 7,000 acres at the mouth, side slope 1½ to 1.

IRRIGATION AND DRAINAGE INVESTIGATIONS
U S DEPARTMENT OF AGRICULTURE OFFICE OF EXPERIMENT STATIONS

MAP OF
CASS COUNTY, NORTH DAKOTA
SHOWING
PROPDSED DRAINAGE

JULY 1906

Surveys made in Cooperation with the County
and the State Engineer's Office
John T. Stewart Engineer in Charge



Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	1.25	3.0	1.0	4.0	No. 7	1.00	3.0	....	4.0
No. 2	1.00	3.0	....	4.0	No. 8	1.50	3.0	....	4.0
No. 3	1.75	3.0	1.5	5.0	No. 9	1.00	4.0	1.0	5.0
	1.00	3.0	....	4.0		1.00	3.0	2.0	5.0
No. 4	2.25	3.0	2.0	5.0		3.00	3.0	2.0	4.0
	2.00	3.0	1.0	4.0	No. 10	1.00	3.0	3.0	4.0
No. 5	1.00	3.0	....	4.0	No. 11	1.00	3.0	....	4.0
No. 6	2.75	4.0	2.0	4.0					
	2.00	3.0	....	4.0					

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	2.00	4.0	1.0	6.0	289	$1,831	$3,662
	2.00	3.0	1.0	5.0	194	1,178	2,356
Main B	2.00	7.0	1.0	6.0	356	2,256	4,512
	3.00	4.0	3.0	5.0	213	1,294	3,882
	3.00	3.0	2.0	4.0	133	772	2,316
Main C	1.75	4.0	1.0	7.0	376	2,382	4,169
	2.25	4.0	1.0	3.0	94	546	1,229
	.25	4.0	....	5.0	213	1,294	324
Laterals	15.75	3.0	....	4.0	133	772	12,159
	2.75	4.0	....	4.0	148	860	2,365
	5.00	3.0	....	5.0	194	1,178	5,890
	1.00	4.0	....	5.0	213	1,294	1,294

Right of way 2 miles in length, 33 feet wide, Main A, 8 acres, at $30 per acre	$240
Two highway bridges, Main A, 50 feet, at $5 per foot	250
Contingencies, Main A	500
Cleaning out coulée in section 32, Reed Township, Main B	1,000
Right of way 8 miles in length, 33 feet wide, Main B, 32 acres, at $30 per acre	960
Eight highway bridges, Main B, 160 feet, at $5 per foot	800
Contingencies, Main B	1,100
Right of way 1.75 miles in length, 33 feet wide, Main C, 7 acres, at $30 per acre	210
One highway bridge, Main C, 16 feet, at $5 per foot	80
Contingencies, Main C	500
Cleaning out coulée in sections 14 and 15, Barnes Township, laterals	800
Cleaning out coulée in section 14, Reed Township, laterals	1,200
Cleaning out coulée in section 28, Reed Township, laterals	800
Contingencies, laterals	2,000
Total cost for district:	
Main A	7,008
Main B	14,570
Main C	6,512
Laterals	26,508
Total	54,598
Average cost per acre	1.56

SHEYENNE DISTRICT.

Sheyenne district covers an area of 35,000 acres lying along the west side of the Sheyenne River. Main A drains 32,000 acres at the mouth, side slope 1 to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	1.25	3.0	1.0	4.0	No. 11	1.00	3.0	....	4.0
No. 2	1.25	3.0	....	4.0	No. 12	1.00	3.0	....	5.0
No. 3	1.25	3.0	....	4.0		1.00	3.0	....	4.0
No. 4	1.25	3.0	1.5	5.0	No. 13	1.00	3.0	....	5.0
	2.00	3.0	....	4.0		1.00	3.0	....	4.0
No. 5	1.00	3.0	2.0	5.0	No. 14	1.00	3.0	....	5.0
	2.00	3.0	1.0	4.0		.75	3.0	....	4.0
No. 6	1.00	3.0	....	5.0	No. 15	1.25	3.0	....	4.0
	1.00	3.0	....	4.0	No. 16	1.25	3.0	....	4.0
No. 7	3.00	3.0	2.0	4.0	No. 17	.75	3.0	....	6.0
No. 8	2.75	3.0	....	4.0		3.00	3.0	....	4.0
No. 9	2.50	3.0	2.0	4.0					
No. 10	2.00	3.0	2.5	5.0					
	3.00	3.0	2.0	4.0					

Dimensions and cost of main and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	5.00	10.0	1.0	8.0	533	$2,814	$14,070
	3.00	8.0	1.0	8.0	474	2,503	7,509
	2.00	6.0	1.0	8.0	415	2,191	4,382
	1.50	6.0	2.0	6.0	267	1,410	2,115
	3.00	4.0	2.0	6.0	222	1,172	3,516
	2.00	4.0	1.5	5.0	167	882	1,764
Laterals	29.25	3.0	....	4.0	133	772	22,581
	8.25	3.0	....	5.0	194	1,178	9,718
	.75	3.0	....	6.0	267	1,692	1,269

Right of way 11.5 miles in length, 33 feet wide, Main A, 46 acres, at $30 per acre	$1,380
Nine highway bridges, Main A, 250 feet, at $5 per acre	1,250
Contingencies, Main A	2,900
Contingencies, laterals	3,300
Total cost for district:	
Main A	38,886
Laterals	36,868
Total	75,754
Average cost per acre	2.16

CANFIELD DISTRICT.

Canfield district covers an area of 74,000 acres lying south and east of the Maple River. The ditches in the southwest part of this district are designed to carry the drainage west to the Leonard ditch and south to the county line, but no provision is made for carrying any water from Richland County. A ditch has been partially constructed along the proposed location of Main A. The present ditch is not deep enough with the light grade to properly drain the basin at its head, but the old ditch will decrease the cost of construction by the amount of work already done. The coulée below the mouth of this ditch should be deepened, as at flood time the water runs too near the surface to give good drainage. Main A drains 36,500 acres at the mouth, side slope 1 to 1; Main B drains 10,000 acres at the mouth, side slope 1½ to 1; Main C drains 6,500 acres at the mouth, side slope 1½ to 1; Main D drains 22,000 acres at the mouth, side slope 1 to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*
No. 1	1.75	3.0	1.0	5.0
	1.00	3.0	....	4.0
No. 2	2.00	3.0	1.0	5.0
	1.00	3.0	....	4.0
No. 3	1.50	3.0	1.0	5.0
	2.00	3.0	....	4.0
No. 4	1.50	3.0	1.0	5.0
	2.00	3.0	....	4.0
No. 5	1.00	3.0	....	4.0
No. 6	1.00	3.0	....	5.0
No. 7	1.00	3.0	....	4.0
No. 8	1.25	3.0	....	4.0
No. 9	1.00	3.0	....	4.0
No. 10	1.50	3.0	....	5.0
	1.00	3.0	....	4.0
No. 11	1.00	3.0	....	5.0
	1.00	3.0	....	4.0
No. 12	2.00	3.0	....	4.0
No. 13	1.00	3.0	....	4.0
No. 14	2.00	3.0	....	4.0
No. 15	3.00	3.0	2.0	5.0
	2.00	3.0	5.0	4.0
No. 16	3.00	3.0	2.0	5.0
	1.00	3.0	....	4.0
No. 17	4.00	3.0	3.0	4.0
No. 18	1.00	4.0	1.0	5.0
	4.00	3.0	5.0	4.0
No. 19	0.75	3.0	1.0	5.0
	1.00	3.0	....	4.0
No. 20	.50	3.0	1.0	5.0
	1.00	3.0	....	4.0
No. 21	2.50	3.0	....	4.0
No. 22	1.50	3.0	....	5.0
	1.00	3.0	....	4.0
No. 23	3.00	3.0	1.5	4.0
No. 24	3.00	3.0	1.5	4.0
No. 25	2.00	3.0	....	5.0
	2.00	3.0	....	4.0
No. 26	1.50	3.0	1.0	5.0
	2.00	3.0	....	4.0
No. 27	1.00	3.0	2.0	5.0
	2.00	3.0	3.0	4.0
No. 28	1.00	3.0	....	5.0
	2.00	3.0	....	4.0
No. 29	1.00	3.0	....	5.0
	2.00	3.0	....	4.0
No. 30	1.00	3.0	....	5.0
	2.00	3.0	....	4.0
No. 31	1.00	3.0	....	5.0
	2.00	3.0	....	4.0
No. 32	1.00	3.0	....	5.0
	2.00	3.0	....	4.0

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	5.00	12.0	1.0	8.0	593	$3,131	$15,655
	2.50	10.0	1.0	8.0	533	2,814	7,035
	5.00	6.0	1.4	6.0	267	1,410	7.050
	1.00	3.0	....	4.0	133	722	722
Main B	1.00	8.0	1.0	6.0	378	2,395	2,395
	1.00	4.0	1.0	6.0	289	1,831	1,831
Main C	2.00	5.0	1.0	6.0	311	1,970	3,940
Main D	4.00	10.0	2.0	8.0	533	2,814	11,256
	5.00	8.0	1.5	8.0	474	2,503	12,515
	3.00	8.0	2.0	6.0	311	1,642	4,926
Laterals	55.75	3.0	....	4.0	133	772	43,039
	28.50	3.0	....	5.0	194	1,178	33,573
	1.00	4.0	....	5.0	213	1,294	1,294

Cleaning out 7 miles of coulée, with 12-foot bottom, 4 feet deep, below mouth of Main A, at center of section 20, Mapleton Township	$10,514
Seven highway bridges, Main A, 210 feet, at $5 per foot	1,050
Contingencies, Main A	3,400
Contingencies, Main B	400
Contingencies, Main C	900
Cleaning out 4 miles of coulée, with a 10-foot bottom, 4 feet deep, from the mouth of Main D, at the south side of section 24, Durbin Township, to the junction with Main A coulée in section 8, Mapleton Township	5,248
Right of way 7 miles in length, 33 feet in width, Main D, 28 acres, at $30 per acre	840

Seven highway bridges, Main D, 210 feet, at $5 per foot	$1,050
Contingencies, Main D	2,400
Contingencies, laterals	8,000
Total cost for district:	
Main A	45,426
Main B	4,626
Main C	4,840
Main D	38,235
Laterals	85,906
Total	179,033
Average cost per acre	2.42

ARGUSVILLE DISTRICT.

Argusville district covers an area of 110,000 acres lying north and west of the Maple and Sheyenne rivers and south of the east and west section line, 1 mile south of Gardner. To prevent overflows by the Rush River, a new channel has been designed for this stream, intersecting the old channel near the east line of section 24, Rush River Township. To give the old Argusville ditch a sufficient channel to drain the tributary area, the present channel should be deepened 4 feet. Main A drains 48,000 acres at the mouth, slide slope 1 to 1; Main B drains 160,000 acres at the mouth, side slope 1 to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	4.00	6.0	1.0	6.0	No. 8	2.25	8.0	1.0	6.0
	1.00	4.0	2.0	5.0		1.00	5.0	3.0	5.0
	3.00	3.0	4.0	5.0		3.00	4.0	4.0	5.0
	4.00	3.0	5.0	4.0		4.00	5.0	5.0	4.0
No. 2	3.00	6.0	1.0	6.0	No. 9	.25	4.0	1.0	5.0
	1.00	4.0	2.0	5.0		2.00	3.0	1.0	5.0
	3.00	3.0	4.0	5.0		1.00	3.0	1.0	4.0
	4.00	3.0	5.0	4.0	No. 10	2.00	8.0	1.0	6.0
No. 3	2.00	3.0	1.0	6.0		1.00	5.0	3.0	5.0
	2.00	3.0	1.0	5.0		3.00	4.0	4.0	5.0
	1.00	3.0	1.0	4.0		4.00	5.0	5.0	4.0
No. 4	2.50	6.0	1.0	6.0	No. 11	1.00	3.0	1.0	5.0
	1.00	4.0	2.0	5.0		1.00	3.0	1.0	4.0
	3.00	3.0	3.0	5.0	No. 12[b]	3.00	4.0	2.5	5.0
	4.00	3.0	5.0	4.0		2.00	4.0	3.0	4.0
No. 5	2.50	6.0	1.0	6.0		1.00	3.0	....	4.0
	1.00	4.0	2.0	5.0	No. 13	2.00	3.0	1.0	5.0
	3.00	3.0	4.0	5.0		1.00	3.0	1.0	4.0
	5.00	3.0	5.0	4.0	No. 14	2.00	3.0	1.0	5.0
No. 6	1.75	6.0	1.0	6.0		1.00	3.0	1.0	4.0
	1.00	4.0	2.0	5.0	No. 15	2.00	3.0	1.0	5.0
	3.00	3.0	4.0	5.0	No. 16	1.50	3.0	1.0	5.0
	5.00	3.0	5.0	4.0		1.00	3.0	1.0	4.0
No. 7[a]	2.50	8.0	1.0	6.0					
	1.00	5.0	3.0	5.0					
	3.00	4.0	4.0	5.0					
	1.00	3.0	4.0	5.0					
	4.00	5.0	5.0	4.0					

[a] Laterals 7 to 10 are designed to carry the drainage west to the Great Northern Railroad. Drainage west of the railroad should be taken into the Rush River.

[b] Lateral 12 will carry the drainage west to the Rush River.

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	1.00	16.0	1.0	4.0	296	$1,875	$1,875
	1.25	14.0	1.0	4.0	267	1,692	2,115
	1.00	12.0	1.0	4.0	237	1,502	1,502
	1.00	12.0	1.0	4.0	237	1,502	1,502
	1.25	10.0	1.0	4.0	207	1,312	1,640
	1.00	10.0	1.0	4.0	207	1,312	1,312
Main B	3.50	40.0	1.0	10.0	1,852	9,779	34,226
	3.00	30.0	2.0	9.0	1,300	6,864	20,592
	5.00	26.0	4.0	8.0	1,007	5.317	26,585
	4.50	18.0	5.0	8.0	770	4,066	18,297
Laterals	29.00	3.0	....	4.0	133	772	22,388
	12.00	5.0	....	4.0	163	847	10,164
	2.00	4.0	....	4.0	148	860	1,720
	28.50	3.0	....	5.0	194	1,178	33,573
	17.25	4.0	....	5.0	213	1,294	22,321
	3.00	5.0	....	5.0	232	1,409	4,227
	2.00	3.0	....	6.0	267	1,692	3,384
	13.75	6.0	....	6.0	333	2,110	29,012
	6.75	8.0	....	6.0	378	2,395	16,166

Contingencies, Main A	$1,000
Right of way 3.5 miles in length, 66 feet wide, Main B, 28 acres, at $30 per acre	840
Right of way 12.5 miles in length, 49.5 feet wide, Main B, 75 acres, at $30 per acre	2,250
Fifteen highway bridges, Main B, 680 feet, at $10 per foot	6,800
Contingencies, Main B	6,600
Contingencies, laterals	14,300
Cleaning out coulée in Raymond Township, from the southwest corner of section 5 to the northeast corner of section 34, to a depth of 5 feet below the ground surface	3,936
Cleaning out ditch and coulée from center of section 15 to the northeast corner of section 2, to a depth of 5 feet below the general surface	2,660
Total cost for district:	
Main A	10,946
Main B	116,190
Cleaning out coulée	3,936
Cleaning out coulée	2,660
Laterals	157,255
Total	290,987
Average cost per acre	2.65

THE GARDNER DISTRICT.

The Gardner district covers an area of 47,300 acres lying between the Rush River district and the Traill County line.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	2.75	5.0	1.0	6.0	No. 5	3.00	4.0	2.0	6.0
	2.00	4.0	2.0	5.0		3.00	3.0	3.0	5.0
	4.00	3.0	4.0	5.0		3.00	3.0	....	4.0
	1.00	3.0	1.0	4.0	No. 6	2.50	5.0	1.0	6.0
No. 2	2.50	5.0	1.0	6.0		3.00	3.0	4.0	5.0
	3.00	3.0	3.0	5.0		4.00	3.0	4.0	4.0
	3.00	3.0	4.0	4.0	No. 7	2.50	5.0	1.0	6.0
No. 3	3.50	5.0	1.0	6.0		3.00	3.0	3.0	5.0
	3.00	3.0	4.0	5.0		5.00	3.0	4.0	4.0
	3.00	3.0	3.5	4.0					
No. 4	2.50	5.0	1.0	6.0					
	1.00	4.0	2.0	5.0					
	3.00	3.0	4.0	5.0					
	3.00	3.0	4.0	4.0					

Summary of laterals.

Length.	Bottom width.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
Miles.	*Feet.*	*Feet.*	*Cu. yds.*		
22.00	3.0	4.0	133	$772	$16,984
22.00	3.0	5.0	194	1,178	25,916
3.00	4.0	5.0	213	1,294	3,882
3.00	4.0	6.0	298	1,831	5,493
16.25	5.0	6.0	311	1,970	32,012

Contingencies, laterals	$8,400
Cleaning out coulée in sections 2 and 3, Noble Township	2,000
Cleaning out coulée in section 14, Noble Township	2,000
Cleaning out coulée in sections 27 and 34, Noble Township	2,500
Total cost for district:	
Cleaning out coulée	2,000
Cleaning out coulée	2,000
Cleaning out coulée	2,500
Laterals	92,687
Total	99,187
Average cost per acre	2.10

HUNTER DISTRICT.

Hunter district covers an area of 24,000 acres in the vicinity of Hunter. The head of the coulée should be cleaned out until it has an 8-foot bottom and a depth of 6 feet below the surface to the mouth of Main B, and above Main B a 6-foot bottom and a depth of 5 feet. Where needed, lateral ditches should be constructed along the section lines, west, the size of Nos. 6 and 8. Mains A and B are intended as a continuation of the coulées which come through the ridges at Hunter and Arthur. Main A drains 17,000 acres at the mouth, side slope 1½ to 1. Main B drains 4,000 acres at the mouth, side slope 1½ to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	2.00	4.0	3.5	5.0	No. 4	1.75	3.0	....	4.0
	1.00	3.0	....	5.0	No. 5	1.50	3.0	....	4.0
	2.00	3.0	....	4.0	No. 6	4.50	3.0	....	4.0
No. 2	1.25	3.0	....	4.0	No. 7	1.00	3.0	....	4.0
No. 3	1.25	3.0	....	4.0	No. 8	3.50	3.0	....	4.0

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	5.00	6.0	4.0	5.0	250	$1,518	$7,590
Main B	4.00	4.0	4.0	5.0	213	1,294	5,176
Cleaning out coulée	2.00	8.0	....	6.0	378	2,395	4,790
	2.00	6.0	....	5.0	250	1,518	3,036
Laterals	2.00	4.0	....	5.0	213	1,294	2,588
	1.00	3.0	....	5.0	194	1,178	1,178
	16.75	3.0	....	4.0	133	772	12,913

Five highway bridges, Main A, 125 feet, at $5 per foot	$625
Contingencies, Main A	800
Four highway bridges, Main B, 80 feet, at $5 per foot	400
Contingencies, Main B	600
Contingencies, laterals	1,700
Total cost for district:	
Cleaning out coulée	7,826
Main A	9,015
Main B	6,176
Laterals	18,397
Total	41,414
Average cost per acre	1.73

TRAILL COUNTY.

(See map, Pl. III.)

ELM RIVER DISTRICT.

Elm River district includes an area of 62,000 acres, drained by the Elm River. Mains 6 to 10 are designed with a capacity sufficient to carry the drainage 6 miles west of the railroad. The north branch of the Elm River is very crooked and the channel obstructed by bushes. To properly drain the territory west of the area surveyed, the upper end of this branch should be cleaned. This could best be done by dredging, beginning near the south line of section 26, Bloomfield township, and constructing a channel with an 8-foot bottom and 7 feet deep to the north side of section 5. This channel would be approximately 9 miles in length, having a fall of about 4 feet per mile, and would cost $27,000. To prevent overflows on the lower end of the river a channel 12 feet in bottom width and 9 feet in depth should be started in section 31, Hillsboro district, and carried to its junction with the main Elm, a distance of approximately 10 miles, having a fall of about 4 feet per mile, and would cost $45,000. Part of the cost of the lower work should be charged to the south side of Hillsboro district, as it would prevent overflows damaging the land east, while part of the cost of the upper work should be paid by the territory lying west of the area surveyed.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	3.50	3.0	1.0	5.0	No. 11	2.00	3.0	1.0	5.0
	2.00	3.0	....	4.0		1.00	3.0	....	4.0
No. 2	2.00	3.0	....	5.0	No. 12	1.50	3.0	....	4.0
	2.00	3.0	....	4.0	No. 13	1.25	3.0	....	4.0
No. 3	1.00	3.0	....	4.0	No. 14	1.00	3.0	....	4.0
No. 4	2.75	3.0	....	5.0	No. 15	2.00	3.0	....	5.0
	4.00	3.0	....	4.0		3.00	3.0	....	4.0
No. 5	1.25	3.0	....	5.0	No. 16	1.00	3.0	....	5.0
	4.00	3.0	....	4.0		3.00	3.0	....	4.0
No. 6	1.75	4.0	3.5	5.0	No. 17	2.00	3.0	2.0	5.0
	3.00	3.0	....	5.0		2.00	3.0	1.0	4.0
No. 7	1.75	4.0	....	5.0	No. 18	2.50	3.0	....	4.0
	3.00	3.0	....	5.0	No. 19	1.25	3.0	....	5.0
No. 8	1.25	4.0	....	5.0		2.00	3.0	....	4.0
	3.00	3.0	....	5.0	No. 20	1.50	3.0	....	5.0
No. 9	1.25	4.0	....	5.0		1.25	3.0	....	4.0
	2.00	3.0	....	5.0	No. 21	2.00	3.0	....	4.0
No. 10	1.00	4.0	....	5.0	No. 22	1.75	3.0	....	4.0
	2.00	3.0	....	5.0					

Dimensions and cost of laterals.

Length.	Bottom width.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
Miles.	*Feet.*	*Feet.*	*Cu. yds.*		
35.25	3.0	4.0	133	$772	$27,213
32.25	3.0	5.0	194	1,178	37,990
7.00	4.0	5.0	213	1,294	9,058

Contingencies	$7,500
Total cost of laterals for district	81,761
Average cost per acre	1.32

HILLSBORO DISTRICT.

The Hillsboro district covers an area of 52,500 acres, lying between the Elm and Goose Rivers and east of Bloomfield township.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	2.00	3.0	4.0	4.0	No. 7	1.50	5.0	1.0	6.0
No. 2	1.00	3.0	....	5.0		4.00	5.0	2.1	5.0
	4.00	3.0	4.0	4.0		2.00	3.0	....	5.0
No. 3	3.50	3.0	3.0	5.0		4.00	3.0	....	4.0
	5.00	3.0	5.0	4.0	No. 8	3.00	4.0	2.0	5.0
No. 4	3.50	4.0	3.0	5.0		2.00	3.0	....	5.0
	3.00	3.0	5.0	5.0		4.00	3.0	....	4.0
	4.00	3.0	3.0	4.0	No. 9	2.75	3.0	5.0	4.0
No. 5	3.50	4.0	3.0	5.0	No. 10	4.00	3.0	3.0	4.0
	3.00	3.0	5.0	5.0	No. 11	1.50	3.0	....	4.0
	4.00	3.0	6.0	4.0	No. 12	2.75	3.0	....	4.0
No. 6	2.00	4.0	1.5	6.0	No. 13	1.75	3.0	....	4.0
	3.00	4.0	3.0	5.0					
	2.00	3.0	3.0	5.0					
	4.00	3.0	5.0	4.0					

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IRRIGATION AND DRAINAGE INVESTIGATIONS

U S DEPARTMENT OF AGRICULTURE OFFICE OF EXPERIMENT STATIONS

MAP OF

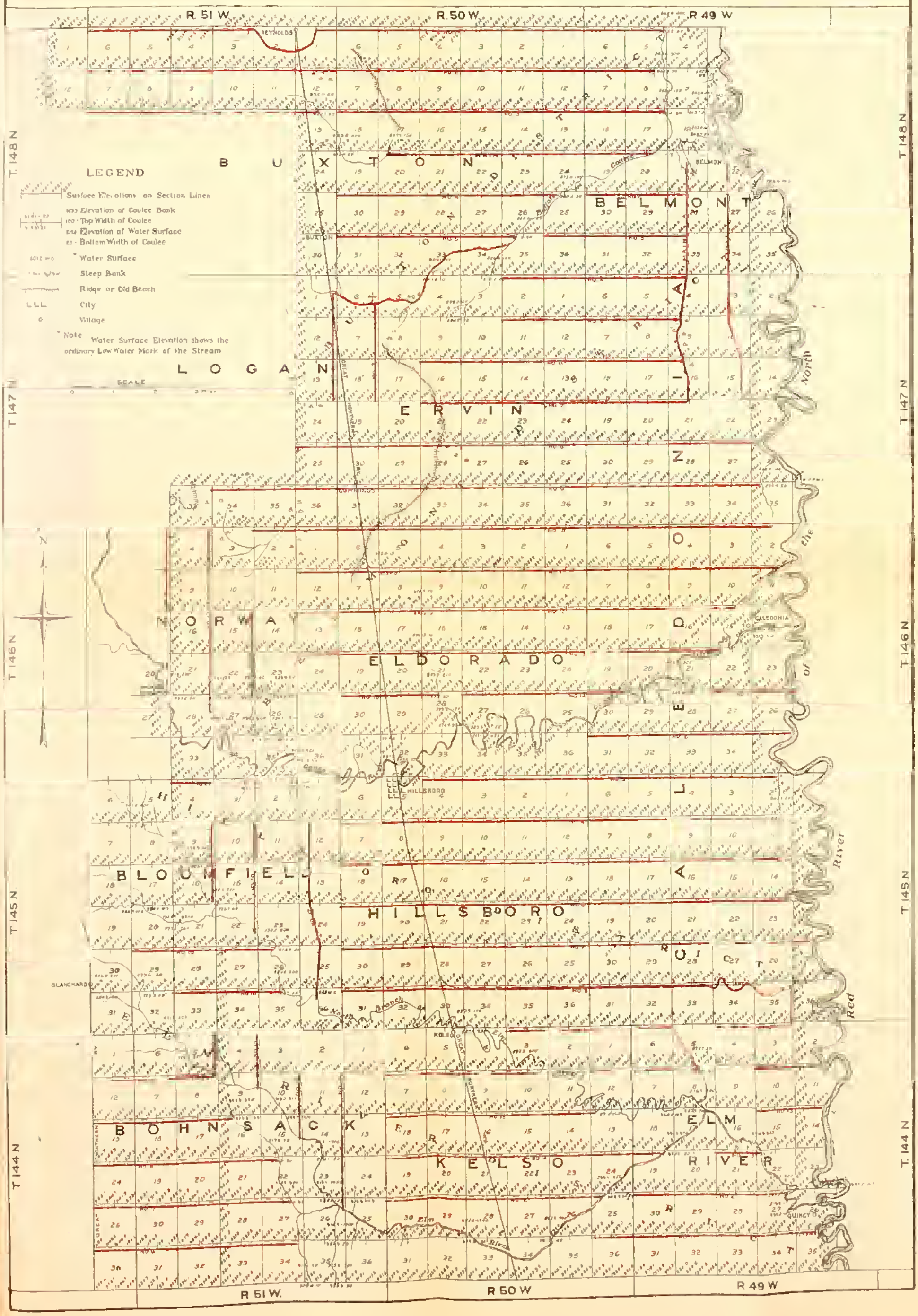
TRAILL COUNTY, NORTH DAKOTA

SHOWING

PROPDSED DRAINAGE

JULY 1906

Surveys made in Cooperation with the County
and the State Engineer's Office.
[illegible] Engineer in Charge



Dimensions and cost of laterals.

Length.	Bottom width.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
Miles.	*Feet.*	*Feet.*	*Cu. yds.*		
43.75	3.0	4.0	133	$772	$33,775
16.50	3.0	5.0	194	1,178	19,437
2.00	4.0	6.0	289	1,831	3,662
1.50	5.0	6.0	311	1,970	2,955
4.00	5.0	5.0	232	1,409	5,636
13.00	4.0	5.0	213	1,294	16,822

Cleaning out coulée in section 11, T. 145, R. 49	$800
Cleaning out coulée in sections 34 and 35, T. 145, R. 49	2,000
Cleaning out coulée in section 5, T. 144, R. 49	600
Contingencies	8,500
Total cost of laterals for district	94,187
Average cost per acre	1.79

BELMONT DISTRICT.

Belmont district covers an area of 83,000 acres, lying between Goose River and Buffalo Coulée. Main A drains 18,000 acres at mouth, side slope 1½ to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*
No. 1	3.00	3.0	1.0	6.0
	3.00	3.0	1.0	5.0
No. 2	2.50	3.0	3.0	4.0
No. 3	3.50	3.0	3.0	4.0
No. 4	4.50	3.0	4.0	4.0
No. 5	4.00	3.0	5.0	4.0
No. 6	3.50	4.0	6.0	4.0
	3.00	3.0	....	4.0
No. 7	3.50	4.0	....	4.0
	3.00	3.0	....	4.0
No. 8	1.25	4.0	2.0	6.0
	4.00	3.0	....	5.0
	2.00	4.0	....	4.0
	4.00	3.0	....	4.0
No. 9	1.25	5.0	1.5	6.0
	3.00	5.0	2.0	5.0
	3.00	3.0	4.0	5.0
	3.00	4.0	....	4.0
	3.00	3.0	....	4.0
No. 10	4.50	5.0	2.0	5.0
	3.00	3.0	....	5.0
	3.00	4.0	....	4.0
	2.00	3.0	....	4.0
No. 11	1.75	4.0	2.0	6.0
	3.00	4.0	2.0	5.0
	3.00	4.0	....	4.0
	4.00	3.0	....	4.0
No. 12	1.75	4.0	2.0	6.0
	3.00	3.0	3.0	5.0
	4.00	4.0	....	4.0
	3.00	3.0	....	4.0
No. 13	3.25	3.0	3.0	5.0
	4.00	4.0	3.0	4.0
	3.00	3.0	....	4.0
No. 14	4.00	3.0	3.0	4.0
No. 15	2.50	3.0	....	4.0
No. 16	2.00	3.0	....	4.0
No. 17	2.00	3.0	....	5.0
	2.00	3.0	....	4.0
No. 18	2.00	4.0	....	4.0
	2.00	3.0	....	4.0

Dimensions and cost of main and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	3.50	12.0	1.0	7.0	493	$2,603	$9,110
	1.00	10.0	1.0	6.0	356	1,880	1,880
	1.00	8.0	1.0	6.0	311	1,642	1,642
Laterals	52.00	3.0	....	4.0	133	772	40,144
	28.00	4.0	....	4.0	148	860	24,080
	21.25	3.0	....	5.0	194	1,178	25,033
	3.00	4.0	....	5.0	213	1,294	3,882
	7.50	5.0	....	5.0	232	1,409	10,567
	3.00	3.0	....	6.0	267	1,692	5,076
	4.75	4.0	....	6.0	289	1,831	8,697
	1.25	5.0	....	6.0	311	1,970	2,462

Right of way 5.5 miles in length, 33 feet wide, Main A, 22 acres, at $30 per acre	$660
Five highway bridges, Main A, 130 feet, at $5 per foot	650
Contingencies, Main A	1,400
Cleaning out coulée in section 35, T. 147, R. 49 W	1,000
Contingencies, laterals	12,000
Total cost for district:	
Main A	15,342
Laterals	132,941
Total	148,283
Average cost per acre	1.79

BUXTON DISTRICT.

Buxton district covers an area of 36,400 acres drained by Buffalo coulée. Mains A and B are designed to carry the drainage of that portion of Buxton Township which was not surveyed. This area can probably be drained by running the ditches along the section line north into Main B. Main A drains 23,000 acres at mouth, side slope 1½ to 1; Main B drains 16,000 acres at mouth, side slope 1½ to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*
No. 1	3.00	7.0	1.0	6.0
	3.00	4.0	3.0	5.0
	4.00	4.0	9.0	4.0
	4.00	3.0	4.0	4.0
No. 2	1.00	7.0	1.0	6.0
	2.00	4.0	3.0	5.0
	3.00	3.0	4.0	5.0
	4.00	4.0	6.0	4.0
	4.00	3.0	....	4.0
No. 3	1.00	4.0	1.0	6.0
	1.00	3.0	3.0	5.0
	2.00	4.0	5.0	4.0
	4.00	3.0	....	4.0
No. 4	2.50	3.0	2.0	5.0
	3.00	3.0	12.0	5.0
No. 5	1.25	3.0	....	5.0
	3.00	3.0	....	4.0
No. 6	5.00	4.0	4.0	4.0
No. 7	2.25	3.0	....	4.0
No. 8	2.50	3.0	....	4.0

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	2.75	7.0	3.0	6.0	356	$2,255	$6,201
	3.75	6.0	4.0	6.0	333	2,110	7,912
Main B	2.50	5.0	10.0	6.0	311	1,970	4,925
	2.00	4.0	8.0	6.0	289	1,831	3,662
	1.00	3.0	5.0	6.0	267	1,692	1,692
Laterals	19.75	3.0	....	4.0	133	772	15,247
	15.00	4.0	....	4.0	148	860	12,900
	10.75	3.0	....	5.0	194	1,178	12,654
	5.00	4.0	....	5.0	213	1,294	6,470
	1.00	4.0	....	6.0	289	1,831	1,831
	4.00	7.0	....	6.0	356	2,256	9,024

Contingencies, Main A	$1,400
Contingencies, Main B	1,000
Contingencies, laterals	5,700
Total for district:	
Main A	15,513
Main B	11,279
Laterals	63,826
Total	90,618
Average cost per acre	2.49

GRAND FORKS COUNTY.

(See map, Pl. IV.)

REYNOLDS DISTRICT.

Reynolds district covers an area of 48,000 acres lying south and east of Elm Coulée. Main A drains 15,000 acres at south side of section 17, side slope 1½ to 1; Main B drains 8,000 acres at mouth, side slope 1½ to 1; Main C drains 5,000 acres at mouth, side slope 1½ to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	1.50	3.0	1.0	5.0	No. 7	2.00	3.0	....	4.0
	1.00	3.0	1.5	4.0	No. 8	1.25	3.0	....	4.0
No. 2	2.25	3.0	1.0	6.0	No. 9	1.25	3.0	....	4.0
	2.00	3.0	2.0	5.0	No. 10	2.25	3.0	....	4.0
	2.00	3.0	5.0	4.0	No. 11	1.25	3.0	1.0	6.0
No. 3	2.00	3.0	3.0	4.0		4.00	3.0	5.0	4.0
No. 4	.75	3.0	6.0	4.0	No. 12	2.75	4.0	6.0	4.0
No. 5	1.25	4.0	1.0	5.0		5.00	3.0	7.5-10.0	4.0
	1.00	3.0	1.0	5.0	No. 13	4.75	3.0	7.5-16.0	4.0
	2.00	3.0	4.0	4.0	No. 14	4.00	3.0	8.5-12.0	4.0
No. 6	1.25	3.0	....	4.0					

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	1.0	5.0	2.5	6.0	311	$1,970	$1,970
	1.0	5.0	1.5	6.0	311	1,970	1,970
	1.0	3.0	1.0	6.0	267	1,692	1,692
Main B	1.5	7.0	1.0	6.0	356	2,256	3,384
	2.0	6.0	1.0	6.0	333	2,110	4,220
	1.0	4.0	6.0	5.0	213	1,294	1,294
Main C	2.5	4.0	1.0	6.0	289	1,831	4,577
	2.0	3.0	2.0	5.0	194	1,178	2,356
Laterals	33.50	3.0	....	4.0	133	772	25,862
	2.75	4.0	....	4.0	148	860	2,365
	4.50	3.0	....	5.0	194	1,178	5,301
	1.25	4.0	....	5.0	213	1,294	1,617
	3.50	3.0	....	6.0	267	1,692	5,922

Right of way 3 miles in length, 33 feet wide, Main A, 12 acres, at $30 per acre	$360
Three highway bridges, Main A, 70 feet, at $5 per foot	350
Contingencies, Main A	500
Contingencies, Main B	900
Contingencies, Main C	700
Contingencies, laterals	4,200
Cleaning out Coven Creek to where it is crossed by the Great Northern Railroad, 9 miles, at $500 per mile	4,500
Total cost for district:	
Main A	6,842
Main B	9,798
Main C	7,633
Cleaning out Coven Creek	4,500
Laterals	45,267
Total	74,040
Cost per acre	1.54

THOMPSON DISTRICT.

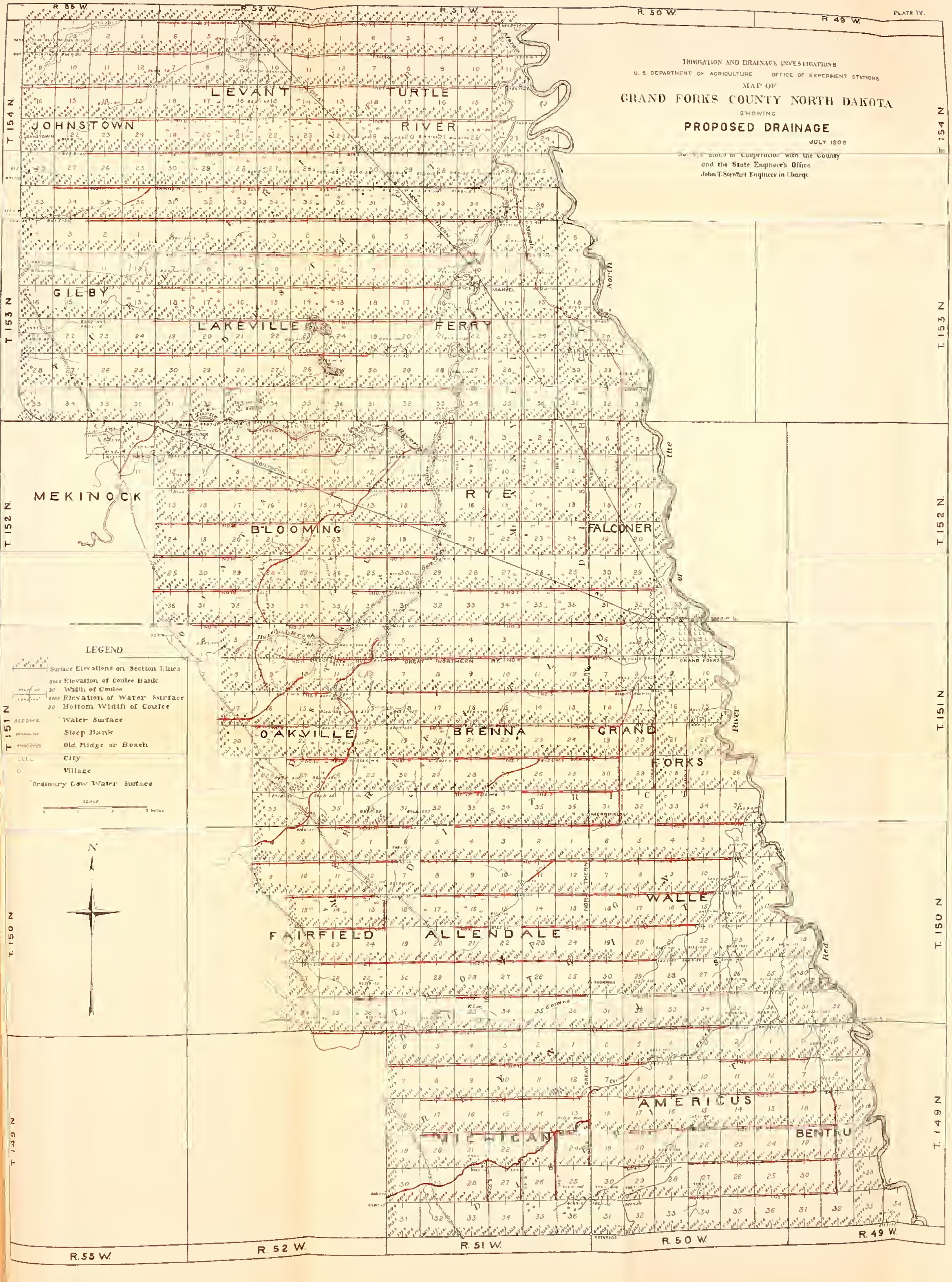
Thompson district covers an area of 30,000 acres lying between Elm Coulée and the northern tier of sections in Allendale and Walle townships. Main A drains 9,000 acres at mouth, side slope 1½ to 1; Main B drains 7,000 acres at mouth, side slope 1½ to 1; Main C drains 26,000 acres at mouth, side slope 1½ to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	2.00	3.0	1.5–4.0	5.0	No. 5	2.25	3.0	2.0	5.0
	2.00	3.0	6.0	4.0		3.00	3.0	6.0	4.0
No. 2	.75	3.0	10.0	4.0	No. 6	1.00	3.0	8.0	4.0
No. 3	2.75	3.0	2.0	5.0	No. 7	2.00	5.0	2.0	5.0
	2.00	3.0	6.0	4.0		3.00	3.0	4.0	5.0
No. 4	3.00	3.0	5.0	4.0		5.00	3.0	4.0	4.0

U. S. Dept. of Agr., Bul. 189, Office of Expt. Stations   Irrig. and Drain. Invest.

PLATE IV.



IRRIGATION AND DRAINAGE INVESTIGATIONS

U. S. DEPARTMENT OF AGRICULTURE   OFFICE OF EXPERIMENT STATIONS

MAP OF

GRAND FORKS COUNTY NORTH DAKOTA

SHOWING

PROPOSED DRAINAGE

JULY 1906

Surveys made in Cooperation with the County
and the State Engineer's Office
John T. Stewart Engineer in Charge

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	1.50	7.0	1.0	6.0	356	$2,256	$3,384
	2.00	5.0	3.0	5.0	232	1,409	2,818
	2.00	4.0	3.0	5.0	213	1,294	2,588
Main B	7.00	4.0	7.0	4.0	148	840	5,880
Main C	6.50	7.0	6.0	5.0	268	1,627	10,575
Laterals	16.75	3.0	....	4.0	133	772	12,931
	10.00	3.0	....	5.0	194	1,178	11,780
	2.00	5.0	....	5.0	232	1,409	2,818

Contingencies, Main A	$880
Contingencies, Main B	600
Contingencies, Main C	1,100
Contingencies, laterals	2,700
Total cost for district:	
Main A	9,670
Main B	6,480
Main C	11,675
Laterals	30,229
Total	58,054
Cost per acre	1.94

MERRIFIELD DISTRICT.

Merrifield district covers an area of 42,800 acres, lying between the Thompson district and the east and west line of the Great Northern Railway. Main A drains 33,000 acres at mouth, side slope 1½ to 1; Main B drains 17,000 acres at mouth, side slope 1½ to 1; Main C drains 6,000 acres at mouth, side slope 1½ to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	2.00	3.0	1.0	5.0	No. 8	1.50	3.0	....	4.0
No. 2	2.00	3.0	2.0	4.0	No. 9	1.00	3.0	2.5	5.0
No. 3	2.75	3.0	1.0	5.0		2.00	3.0	....	4.0
No. 4	2.50	3.0	1.0	6.0	No. 10	0.75	3.0	....	4.0
	3.00	3.0	3.0	5.0	No. 11	3.00	4.0	5.1	4.0
	1.00	3.0	6.0	4.0		2.00	3.0	....	4.0
No. 5	6.00	3.0	1.5	6.0	No. 12	2.75	3.0	....	4.0
	1.00	3.0	....	4.0	No. 13	4.25	3.0	....	4.0
No. 6	1.00	3.0	....	4.0	No. 14	2.75	3.0	....	4.0
No. 7	2.50	3.0	....	4.0	No. 15	2.75	3.0	....	4.0

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	0.75	8.0	4.0	6.0	378	$2,395	$1,796
	1.00	8.0	1.3	6.0	378	2,395	2,395
	1.00	4.0	2.0	6.0	289	1,831	1,831
	1.00	3.0	2.0	6.0	267	1,692	1,692
Main B	2.00	8.0	2.5	6.0	378	2,395	4,790
	3.00	6.0	3.0	6.0	333	2,110	6,330
Main C	2.50	4.0	2.5	5.0	213	1,294	3,235
Laterals	26.25	3.0	....	4.0	133	772	20,265
	3.00	4.0	....	4.0	148	840	2,520
	8.75	3.0	....	5.0	194	1,178	10.308
	8.50	3.0	....	6.0	267	1,692	14,382

Right of way, Main A, 5 acres, at $30 per acre	$150
Four highway bridges, Main A, 100 feet, at $5 per foot	500
Contingencies, Main A	700
Contingencies, Main B	1,100
Contingencies, Main C	400
Contingencies, laterals	4,700
Cleaning out coulée in sections 29 and 30, Brenna Township	2,746
Cleaning out coulée in sections 26 and 27, Brenna Township	1,400

Total cost for district:

Main A	9,064
Main B	12,220
Main C	3,635
Cleaning out coulée	2,746
Cleaning out coulée	1,400
Laterals	52,175
Total	81,240
Cost per acre	1.90

MANVEL DISTRICT.

Manvel district covers an area of 37,000 acres, lying north of the main line of the Great Northern Railway and east of Salt Coulée and Turtle River. A number of laterals in this district discharge into the Marais. The Marais is badly clogged with bushes and drift and should be cleaned out sufficiently to make a continuous channel throughout its course.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	2.25	3.0	....	4.0	No. 5	5.75	3.0	2.5	5.0
No. 2	3.50	4.0	2.0	5.0	No. 6	2.75	4.0	....	5.0
	3.00	3.0	3 to 1	5.0		3.00	3.0	....	5.0
	1.00	3.0	....	4.0	No. 7	2.00	3.0	1.0	6.0
No. 3	2.00	5.0	1.0	6.0		4.00	3.0	1.0	5.0
	7.00	3.0	3.0	5.0	No. 8	6.00	3.0	3.0	5.0
No. 4	7.50	3.0	3.0	5.0					

Summary of laterals.

Length.	Bottom width.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
Miles.	*Feet.*	*Feet.*	*Cu. yds.*		
3.25	3.0	4.0	133	$772	$2,509
6.25	4.0	5.0	213	1,294	8,087
36.25	3.0	5.0	194	1,178	42,702
2.00	5.0	6.0	311	1,970	3,940
2.00	3.0	6.0	267	1.692	3,384

Contingencies	$6,000
Total cost for district:	
Cleaning out Marais	$5,000
Laterals	66,622
Total	71,622
Cost per acre	1.94

OJATA DISTRICT.

Ojata district includes the territory lying west of Salt Coulée. Part of this district is covered by alkaline basins several feet lower than the surrounding prairie. The area outside of the basins is approximately 20,000 acres, which would be benefited by lateral drainage emptying into the basins. It is doubtful if it would be profitable to attempt any drainage of the basins on account of their alkaline nature and the large cost in proportion to the area benefited. If main channels were constructed through these basins they would prevent stagnant water and would increase the value of the basins for pasture.

Salt Coulée drains 21 square miles from the west, and a channel with a 10-foot bottom, 4 feet deep, constructed through this coulée, beginning one-half mile below the Great Northern Railway and carried up to the west boundary of the area surveyed, would cost about $15,000. In Oakville Township a similar channel could be constructed at the outlet of Main A down into section 10 for about $1,000. In sections 4 and 9 a channel with a 6-foot bottom and 4 feet deep could be constructed for about $1,500. A channel extending through the basin in Blooming Township with 8-foot bottom and 4 feet deep would cost about $15,000. To prevent Salt Coulée from overflowing to the east through the depression in the bank in section 18, Brenna Township, the road culvert should be taken out and a high road grade maintained along the west line of section 18 across this depression. Main A drains 17,000 acres, side slope 1½ to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	1.50	3.0	4.0	4.0	No. 9	1.75	3.0	....	4.0
No. 2	1.50	3.0	....	5.0		.75	3.0	....	4.0
	1.00	3.0	....	4.0	No. 10	1.75	3.0	....	4.0
No. 3	1.50	3.0	....	5.0	No. 11	4.00	3.0	....	4.0
	1.00	3.0	....	4.0	No. 12	2.50	4.0	....	5.0
No. 4	1.25	3.0	....	4.0		3.00	3.0	....	4.0
No. 5	2.00	3.0	....	4.0	No. 13	4.50	3.0	6.0	4.0
No. 6	1.00	3.0	....	4.0	No. 14	3.00	3.0	....	4.0
No. 7	.75	3.0	....	4.0	No. 15	3.00	3.0	....	4.0
No. 8	1.00	3.0	....	4.0	No. 16	2.00	3.0	....	4.0

Dimensions and cost of main and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total. cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	2.00	8.0	6.0	5.0	287	$1,742	$3484
Laterals	33.25	3.0	....	4.0	133	772	25,669
	3.00	3.0	....	5.0	194	1,178	3,534
	2.50	4.0	....	4.0	213	1,294	3,235

Contingencies, Main A	$400
Contingencies, laterals	2,900
Total cost for district:	
Main A	3,884
Laterals	35,338
Total	39,222
Cost per acre	1.96

TURTLE RIVER.

Turtle River drains 328 square miles, and overflows to the north. As the channel is very crooked and full of drift it would be advisable to open up a new channel and make cut-offs, as shown on the maps.

Turtle River.

	Length.	Bottom width.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Cu. yds.*		
New channel	7.25	30.0	10.0	1,482	$7,825	$56,731
3 cut-offs	1.00	30.0	10.0	....	....	8,000
Contingencies	....	....	....	....	....	6,000
	....	....	....	....	....	70,731

TURTLE RIVER DISTRICT.

Turtle River district covers an area of 104,000 acres, lying north and west of the Turtle River. On account of the alkaline condition of the lands of this district the ditches should be made extra deep. Main A drains 6,000 acres at mouth, side slope 1½ to 1; Main B drains 18,000 acres at mouth, side slope 1½ to 1; Main C drains 27,000 acres at mouth, side slope 1½ to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet*	*Feet.*
No. 1	2.25	3.0	1.0	6.0	No. 10	6.00	3.0	3.0	5.0
	3.00	3.0	1.5-4	5.0		2.00	3.0	....	4.0
	2.00	3.0	....	4.0	No. 11	2.00	3.0	....	4.0
No. 2	2.50	3.0	2.0	4.0	No. 12	6.00	4.0	2.0	6.0
No. 3	2.75	3.0	1.0	6.0		3.00	3.0	2.5	5.0
	2.00	3.0	....	5.0		3.00	3.0	....	4.0
	2.00	3.0	....	4.0	No. 13	3.25	3.0	2.0	6.0
No. 4	4.00	3.0	3.0	4.0		2.00	3.0	1.0	5.0
No. 5	2.25	3.0	1.0	6.0		3.00	3.0	4.0	4.0
	2.00	3.0	....	5.0	No. 14	1.50	3.0	2.0	6.0
	2.00	3.0	....	4.0		4.00	3.0	....	5.0
No. 6	1.25	3.0	....	4.0		3.00	3.0	....	4.0
No. 7	3.75	3.0	5.0	4.0	No. 15	1.75	6.0	1.0	6.0
No. 8	4.25	3.0	4.0	5.0		5.00	4.0	3.0	5.0
	2.00	3.0	4.0	4.0		4.00	3.0	....	4.0
No. 9	1.75	3.0	1.0	5.0					
	2.00	3.0	....	4.0					

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	4.00	4.0	2.5	5.0	213	$1,294	$5,176
Main B	7.50	8.0	2.0	5.0	287	1,742	13,065
Main C	5.50	10.0	2.0	6.0	422	2,674	14,707
	2.00	8.0	4.0	5.0	287	1,742	3,484
	1.00	6.0	6.0	5.0	250	1,518	1,518
Laterals	38.50	3.0	....	4.0	133	772	29,722
	28.00	3.0	....	5.0	194	1,178	32,984
	12.00	3.0	....	6.0	267	1,692	20,304
	5.0	4.0	....	5.0	213	1,294	6,470
	6.00	4.0	....	6.0	289	1,831	10,986
	1.75	6.0	....	6.0	333	2,110	3,693

Cleaning old ditch, Main A	$1,000
Contingencies, Main A	500
Contingencies, Main B	1,300
Contingencies, Main C	2,000
Contingencies, laterals	10,500
Total cost for district:	
Main A	6,676
Main B	14,365
Main C	21,709
Turtle River	70,731
Laterals	114,659
Total	228,140
Cost per acre	2.19

WALSH COUNTY.

(See map, Pl. V.)

ISLAND DISTRICT.

This district includes an area of 5,760 acres lying between the Marais and the Red rivers and is subject to overflow. For this reason the ditch has been designed with a 2 to 1 slope on either side and is computed to drain the area with the water running 4 feet deep.

Main A.

Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
3.00	5.0	1.0	7.0	493	$3,124	$9,372
2.25	4.0	1.0	5.0	260	1,647	3,706
2.00	3.0	1.5	5.0	241	1,527	3,054
Right of way 7.25 miles in length, 33 feet wide, 37.5 acres, at $30 per acre						1,125
Six highway bridges, 160 feet, at $5 per foot						800
Contingencies						1,450
Total						19,507
Cost per acre						3.40

MARAIS DISTRICT.

This district includes an area of 22,400 acres. As the ditch is located in land subject to overflow, it is designed with a 2 to 1 slope and will carry the maximum drainage of the district when running 5 feet deep.

Laterals.

Lateral.	Length.	Bottom width.	Depth.	Lateral.	Length.	Bottom width.	Depth.
	Miles.	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*
No. 1	1.25	3.0	4.0	No. 8	2.25	3.0	4.0
No. 2	1.50	3.0	4.0		1.00	3.0	5.0
No. 3	.5	3.0	4.0	No. 9	1.25	3.0	5.0
No. 4	1.0	3.0	5.0		3.00	3.0	4.0
	1.0	3.0	4.0	No. 10	.75	3.0	4.0
No. 5	2.25	3.0	4.0	No. 11	.75	3.0	4.0
No. 6	.75	3.0	4.0	No. 12	1.25	3.0	5.0
No. 7	.75	3.0	4.0		3.00	3.0	4.0

Dimensions and cost of Main A and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	1.25	10.0	1.0	7.0	622	$3,941	$4,926
	2.25	10.0	1.0	6.0	489	3,098	6,971
	2.50	8.0	1.0	6.0	444	2,813	7,033
	2.00	6.0	1.0	6.0	400	2,534	5,068
	1.0	4.0	1.0	6.0	356	2,255	2,255
Laterals	17.75	3.0	....	4.0	133	772	13,703
	4.50	3.0	....	5.0	194	1,178	5,301

Right of way 8.5 miles in length, 33 feet wide, Main A, 38 acres, at $30 per acre	$1,140
Nine highway bridges, Main A, 240 feet, at $5 per foot	1,200
Contingencies, Main A	3,000
Contingencies, laterals	2,000
Total cost for district:	
Main A	31,593
Laterals	21,004
Total	52,597
Cost per acre	2.30

SALT LAKE DISTRICT.

During high water the Forest River overflows, damaging the land to the east; hence an improvement of the channel necessary to give it the required carrying capacity and prevent the overflow has been designed. The channel should be cleaned out by removing drift and overhanging trees as far as Minto. The area of the district is 14,000 acres.

Forest River drains 644 square miles, side slope 1 to 1.

Laterals.

Lateral.	Length.	Bottom width.	Depth.	Lateral.	Length.	Bottom width.	Depth.
	Miles.	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*
No. 1	2.50	3.0	4.0	No. 4	3.25	3.0	4.0
No. 2	1.50	3.0	5.0	No. 5	1.50	3.0	5.0
	2.00	3.0	4.0		3.00	3.0	4.0
No. 3	1.25	3.0	4.0	No. 6	4.50	3.0	4.0

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Forest River	3.5	35.0	8.0	9.0	1,467	$7,746	$27,111
Laterals	16.50	3.0	4.0	4.0	133	772	12,738
	3.0	3.0		5.0	194	1,178	3,534

Contingencies	$1,600
Total cost for district:	
Forest River	27,111
Laterals	17,872
Total	44,983
Cost per acre	3.21

GRAFTON DISTRICT.

This district includes the area lying north of the Forest and Salt rivers and south of Park River, embracing an area of 95,000 acres. Mains B, C, and D are large enough to carry the drainage of the area west of the limits of the survey, and each of these ditches should be extended west until they intersect the coulees which empty on the surface in the eastern part of range 54. Laterals No. 18, 20, and 21 will each carry the drainage of two sections west of the area surveyed and No. 22 will carry one section west of this area. Main A drains 38,000 acres at the mouth, side slope 1 to 1; Main B drains 20,400 acres at the mouth, side slope 1½ to 1; Main C drains 36,000 acres at the mouth, side slope 1½ to 1; Main D drains 21,000 acres at the mouth, side slope 1½ to 1.

Laterals.

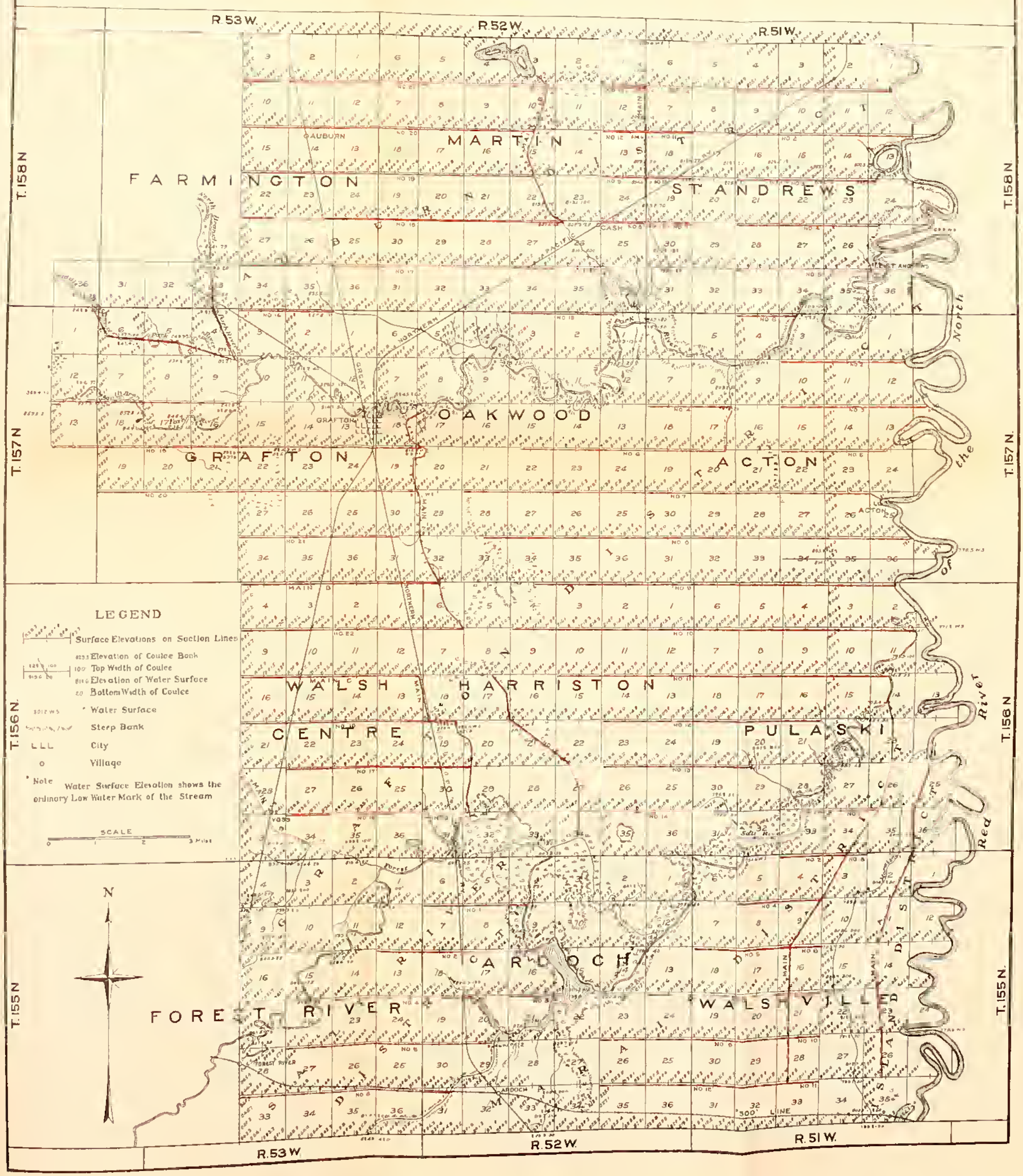
Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	1.00	3.0	....	4.0	No. 11	5.25	3.0	1.0	6.0
No. 2	0.75	3.0	....	5.0		2.00	3.0	2.0	4.0
	2.00	3.0	....	4.0	No. 12	0 75	3.0	1.0	6.0
No. 3	1.25	3.0	....	5.0		2.00	3.0	1.0	5.0
	2.00	3.0	....	4.0		2.00	3.0	2.0	4.0
No. 4	1.75	3.0	....	4.0	Outlet 12	0.75	4 0	....	3.0
No. 5	2.75	3.0	....	5.0	Lateral 13	1.25	3.0	2.0	5.0
Outlet 6	1.00	4.0	....	5.0		2.00	3.0	1 0	4.0
Lateral 6	1.75	3.0	....	5.0	Lateral 14	2.75	3.0	2.0	4.0
	3.00	3 0	....	4 0	Lateral 15	1.50	3.0	1.0	6.0
Lateral 7	2.50	4.0	1.0	6.0		2.00	3.0	1.0	5.0
	1.00	4.0	1 0	5.0		1.25	3.0	1.0	4.0
	3.00	3.0	2.0	5.0	Lateral 16	3.00	3.0	....	4.0
	3.00	3.0	2.0	4.0	Lateral 17	2.00	3.0	1.0	5.0
Lateral 8	3.00	4.0	1.0	6.0		2.00	3.0	....	4.0
	1.00	4.0	1.0	5.0	Lateral 18	2.00	3.0	2.0	5.0
	4.00	3.0	2.0	5.0		2.00	3.0	....	4.0
	1.50	3.0	....	4.0	Lateral 19	3.00	4.0	1.0	6.0
Lateral 9	2.50	4.0	1.0	6.0		3.00	3.0	4.0	5.0
	3.00	4.0	1.0	5.0		2.00	3.0	....	4.0
	2.00	3.0	1.0	5.0	Lateral 20	4 00	3.0	4.0	5.0
	1.00	3.0	....	4.0		3.00	3.0	4.0	4.0
Lateral 10	2.75	4.0	1.5	6.0	Lateral 21	3.00	3.0	4.0	5.0
	1.00	4.0	1.5	5.0		1.00	3.0	4.0	4.0
	2.00	3.0	1.5	5.0	Lateral 22	3.00	3.0	3 0	5.0
	3.00	3.0	2.0	4.0		2.00	3.0	4.0	4.0

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	1.0	25.0	1.0	5.0	556	$2,936.00	$2,936
	1.0	20.0	1.0	5.0	463	2,445.00	2,445
	1.0	18.0	1.0	5 0	426	2,249.00	2,249
	1.0	16 0	1.0	5 0	389	2,054.00	2,054
	1.0	8 0	1.0	5 0	241	1,272.00	1.272
Main B	4 5	6.0	2.5	6 0	333	2,110.71	9,495
Main C	3.0	16 0	2 0	5.0	389	2,054.00	6,162
	1.0	10.0	2.0	7 0	441	2,328.00	2,328
	4 0	6.0	4 0	6.0	333	2,110 00	8,440
Main D	2.5	8.0	2 0	6 0	378	2,395.00	5,987
Laterals	43 25	3.0	....	4 0	133	772.00	33,389
	39.75	3.0	....	5 0	194	1,178.00	46,825
	7.00	4 0	....	5.0	213	1,294.00	9,058
	13 75	4 0	....	6.0	289	1,831 00	25,176
	7.50	3 0	....	6.0	267	1,692.00	12 690
	0.75	4.0	....	3.0	95	587.00	440

IRRIGATION AND DRAINAGE INVESTIGATIONS
U S DEPARTMENT OF AGRICULTURE   OFFICE OF EXPERIMENT STATIONS
MAP OF
WALSH COUNTY, NORTH DAKOTA
SHOWING
PROPOSED DRAINAGE
JULY · 1906

Surveys made in Cooperation with the County
and the State Engineer's Office
John T. Stewart Engineer in Charge



Note Water Surface Elevation shows the ordinary Low Water Mark of the Stream

Twenty per cent added for bends, Main A	$2,191
Right of way 6 miles in length, 33 feet wide, Main A, 24 acres, at $20 per acre	480
Four highway bridges, Main A, 120 feet, at $5 per foot	600
Contingencies, Main A	1,000
Contingencies, Main B	1,000
Right of way 4 miles in length, 33 feet wide, Main C, 16 acres, at $30 per acre	480
Two highway bridges, Main C, 55 feet, at $5 per foot	275
Contingencies, Main C	1,800
Right of way 2½ miles in length, 33 feet wide, Main D, 10 acres, at $30 per acre	300
One highway bridge, Main D, 25 feet, at $5 per foot	125
Contingencies, Main D	600
Contingencies, laterals	12,492
Total cost for district:	
Main A	15,227
Main B	10,495
Main C	19,485
Main D	7,012
South Park River	26,994
Laterals	140,070
Total	219,283
Middle Park River	17,080
Cost per acre	2.31

PARK RIVER IMPROVEMENT.

The south branch of Park River is the cause of considerable damage to the land lying south and east. The overflow occurs in the west part of range 53. On account of the small, crooked channel of this stream a new channel has been designed. This channel should begin a half mile west of the area surveyed and continue along the section line, as shown on the map. The new channel could be constructed along the present course of the river, but on account of the increase in distance it would require a bottom width of 18 feet to give the same carrying capacity as the proposed channel. This improvement should be constructed as a part of the Grafton district.

Both the middle and north branch of Park River have small, crooked channels, and should be improved. An estimate for this improvement has been made for the reaches of these streams which come in the area surveyed. The course of the north branch could be changed by cutting a new channel east along the south line of township 158, intersecting the coulée at the southeast corner of section 35. The part of the channel along the section line would require a 30-foot bottom, 9 feet deep, and the coulée would also require some improving. The construction of this channel would probably develop considerable opposition from landowners. It is believed that by cleaning out the channel below the junction of these branches this cut-off would not be necessary. The improvement of the north branch should be considered as a part of the Auburn district.

Dimensions and cost of mains.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
South Park	4.75	16.0	7.0	10.0	963	$5,085	$24,154
Middle Park	4.0	9.0	5.0	10.0	703.7	3,715	14,860
North Park	2.25	20.0	5.0	10.0	1,111	5,866	13,199

Right of way 4.75 miles in length, 49.5 feet wide, South Park, 28 acres, at $30 per acre	$840
Contingencies, South Park	2,000
Right of way 4 miles in length, 49.5 feet wide, Middle Park, 24 acres, at $30 per acre	720
Contingencies, Middle Park	1,500
Right of way 2.25 miles in length, 49.5 feet wide, North Park, 14 acres, at $30 per acre	420
Contingencies, North Park	1,300

Total cost of Park River improvement:

South Park	26,994
Middle Park	17,080
North Park	14,919

AUBURN DISTRICT.

The Auburn district includes an area of 56,300 acres, lying north of the Park River and south of the Pembina County line. On account of the short length of Mains A and B, they have been computed with a 1½ to 1 slope on either side. A ditch should be run south from the Pembina County line to the north branch of the Park River, along the west line of sections 4, 9, and 16, T. 158, R. 53, to carry the drainage of the country west into the river. Main A drains 8,000 acres at the mouth, side slope 1½ to 1; Main B drains 16,000 acres at the mouth, side slope 1½ to 1.

Laterals.

Lateral.	Length.	Bottom width.	Depth.	Lateral.	Length.	Bottom width.	Depth.
	Miles.	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*
No. 1	2.5	3.0	5.0	No. 13	1.0	3.0	4.0
	1.0	3.0	4.0	No. 14	1.0	3.0	4.0
No. 2	3.25	3.0	5.0	No. 15	2.25	3.0	4.0
	1.0	3.0	4.0	No. 16	1.0	3.0	5.0
No. 3	3.25	3.0	4.0		1.0	3.0	4.0
No. 4	3.25	3.0	4.0	No. 17	5.0	3.0	5.0
No. 5	2.0	3.0	4.0		3.0	3.0	4.0
	1.0	3.0	5.0	No. 18	4.0	3.0	5.0
No. 6	1.25	3.0	4.0		3.0	3.0	4.0
No. 7	1.0	3.0	4.0	No. 19	3.5	3.0	5.0
No. 8	1.0	3.0	4.0		3.0	3.0	4.0
No. 9	1.0	3.0	4.0	No. 20	3.5	3.0	5.0
No. 10	1.0	3.0	4.0		3.0	3.0	4.0
No. 11	1.0	3.0	4.0	No. 21	3.75	3.0	5.0
No. 12	1.0	3.0	4.0		3.0	3.0	4.0

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	3.0	6.0	1.0	6.0	333	$2,110	$6,330
Main B	2.5	8.0	2.0	6.0	378	2,395	5,987
	1.25	6.0	4.0	6.0	333	2,110	2,637
Laterals	38.0	3.0		4.0		772	29,336
	27.5	3.0		5.0		1,178	32,395

Three highway bridges, Main A, 72 feet, at $5 per foot	$360
Contingencies, Main A	450
Right of way, 3.75 miles in length, 33 feet wide, Main B, 15 acres, at $20 per acre.	300
Three highway bridges, Main B, 100 feet, at $5 per foot	500
Contingencies, Main B	500
Contingencies, laterals	6,175
Total cost for district:	
Main A	7,140
Main B	9,924
North Park River	14.919
Laterals	67,906
Total	99,889
Cost per acre	1.79

PEMBINA COUNTY.

(See map, Pl. VI.)

In the southern part of T. 160 N., R. 55 W. and R. 56 W. the natural coulées will furnish sufficient outlets if their channels are cleaned out.

To properly carry the water which comes from the hill land to the west, the coulée from the west line of section 35, Thingvalla Township, to the east line of section 31, Park Township, should have a channel 8 feet in bottom width, with a depth of 6 feet below the level of the adjacent lands. The cost of this improvement would be, approximately, $7,000.

The coulée from the west line of section 15, Thingvalla Township, to the center of section 29, Park Township, should have a channel 8 feet in bottom width, with a depth of 6 feet below the adjacent lands. The cost of this improvement would be, approximately, $10,000.

A ditch constructed along the west side of the Great Northern Railway from the northeast corner of section 36, Park Township, south to Cart Creek, with a 6-foot bottom and 5 feet deep, would furnish an outlet to several sections and prevent flooding of the lands to the east.

WILLOW COULÉE DISTRICT.

Willow Coulée district covers an area of 96,000 acres, drained by Willow Coulée. To properly drain this district it will be necessary to straighten and deepen Willow Coulée and give it an outlet. Willow Coulée drains 106,000 acres at the mouth, side slope 1 to 1; Main A drains 10,000 acres at the mouth, side slope 1½ to 1; Main B drains an area of 10,000 acres at the mouth, side slope 1½ to 1.

Laterals.

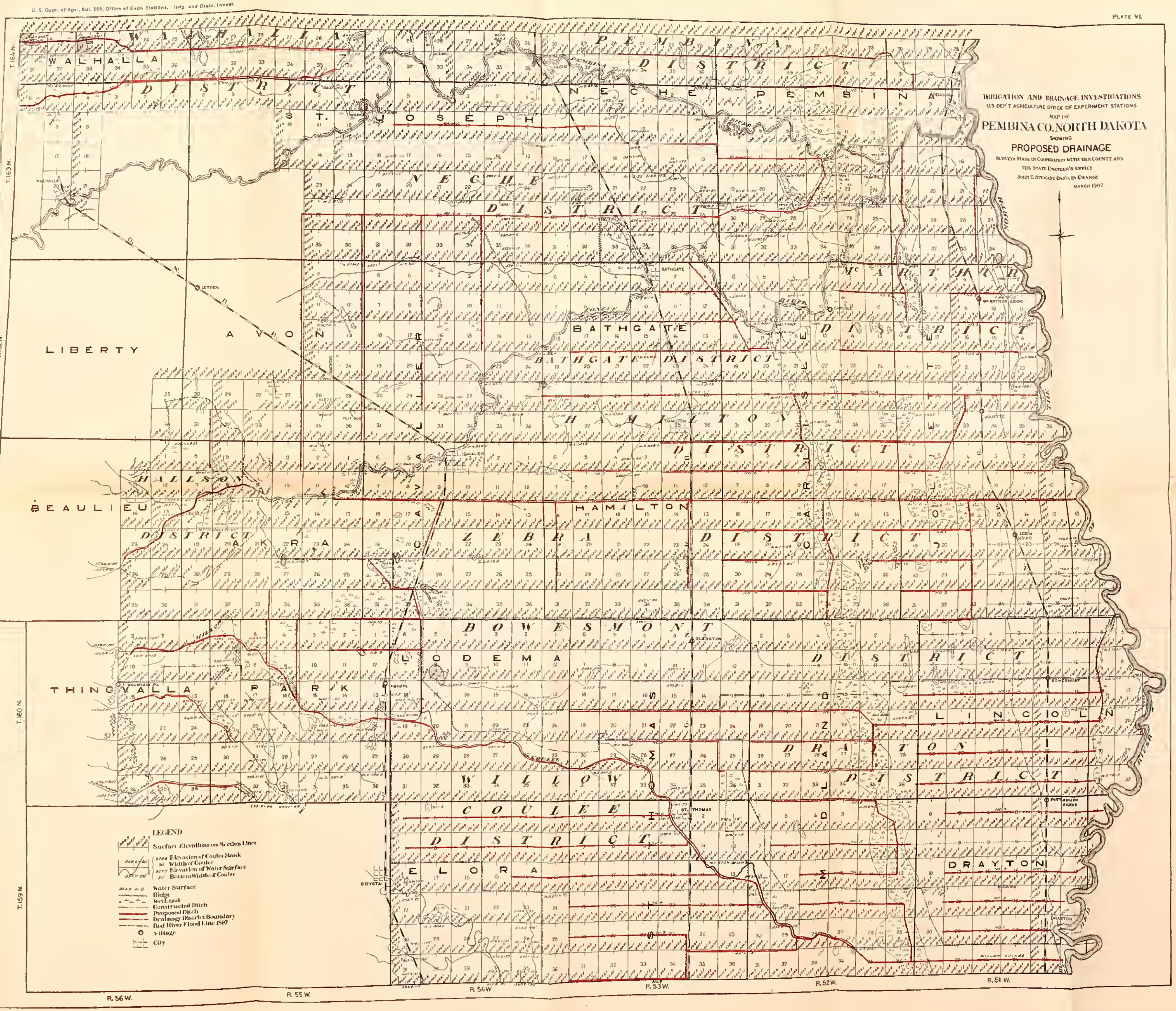
Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	2.0	3	1	6	No. 7	5.0	3	6	5
	3.5	3	4	4		4.5	3	....	4
No. 2	5.0	3	4	4	No. 8	4.3	3	6	5
No. 3	4.5	3	5	4		4.5	3	....	4
No. 4	2.5	5	5	4	No. 9	3.0	3	....	4
	4.0	3	5	4	No. 10	3.0	3	....	4
No. 5[a]	1.4	3	1	5	No. 11	4.2	3	6	4
	3.0	3	....	4	No. 12	3.5	3	4	4
No. 6	3.0	3	5	5					
	4.0	3	....	4					

[a] At mouth of No. 5 old ditch through section 36 should be enlarged to 5 feet in depth, with a 3-foot bottom.

Dimensions and cost of mains and laterals.

Ditch.	Length	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Red River to west line sec. 31, R. 51	5.0	24	1.5	9	1,100	$5,808	$29,040
Center sec. 18, R. 52	8.0	16	3.0	9	833	4,400	35,200
North side sec. 33, R. 53	8.0	12	3.0	9	700	3,696	29,568
Northwest corner sec. 20, R. 54	11.0	8	5.0	8	474	2,503	27,533
Northwest corner sec. 10, R. 56	13.0	8	8.0	6	311	1,642	21,346
Main A	4.0	5	2.0	6	311	1,971	7,884
Main B	3.0	5	2.0	6	311	1,971	5,913
	1.0	4	2.0	6	289	1,831	1,831
	2.0	3	4.0	5	194	1,178	2,356
Laterals	46.7	3	....	4	133	772	36,052
	2.5	5	....	4	163	847	2,117
	13.7	3	....	5	194	1,178	16,138
	2.0	3	....	6	267	1,692	3,384

Right of way 13 miles in length, 49½ feet wide, Willow Coulée, 78 acres, at $30 per acre	$2,340
Right of way 32 miles in length, 33 feet wide, Willow Coulée, 128 acres, at $30 per acre	3,840
Thirty-eight highway bridges, Willow Coulée, 1,170 feet, at $6 per foot	7,020
Contingencies, Willow Coulée	12,000
Right of way 4 miles in length, 33 feet wide, Main A, 16 acres, at $30 per acre	480
Five highway bridges, Main A, 115 feet, at $6 per foot	690
Contingencies, Main A	800
Right of way 6 miles in length, 24½ feet wide, Main B, 18 acres, at $30 per acre	540
Five highway bridges, Main B, 136 feet, at $6 per foot	816
Contingencies, Main B	1,000
Right of way 36 miles in length, on quarter-section lines, 24½ feet wide, laterals, 108 acres, at $30 per acre	3,240
Contingencies, laterals	6,000
Total cost for district:	
Willow Coulée	167,887
Main A	9,854
Main B	12,456
Laterals	66,931
Total	257,128
Cost per acre	2.68



IRRIGATION AND DRAINAGE INVESTIGATIONS
U.S. DEP'T AGRICULTURE OFFICE OF EXPERIMENT STATIONS
MAP OF
PEMBINA CO. NORTH DAKOTA
SHOWING
PROPOSED DRAINAGE
SURVEYS MADE IN COOPERATION WITH THE COUNTY AND
THE STATE ENGINEER'S OFFICE
JOHN T. STEWART ENG'R IN CHARGE
MARCH 1907

DRAYTON DISTRICT.

Drayton district covers an area of 58,000 acres lying north of the Willow Coulée district. Where new ditches outlet into ditches already constructed, the new ditch should be decreased in depth and increased in width, so as to join the old ditch, or the upper part of the old ditch should be improved until it has the same cross section as the new ditch.

The Marais in Lincoln Township from the center line of sec. 19, T. 160 N., R. 50 W. to the Red River, should be cleaned out until the channel is 8 feet in depth, with a bottom width of 20 feet. The cost of this improvement would be, approximately, $15,000. Main A drains an area of 21,700 acres at the mouth, side slope 1 to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	0.8	3	1	5	No. 8	4.3	3	2.0	5
	3.0	3	2	4		2.0	3		4
No. 2	1.2	3	1	5	No. 9	1.5	3	1.0	6
	3.0	3	2	4		3.0	3	2.0	5
No. 3	1.8	3	1	6		2.0	3		4
	1.0	3		5	No. 10	1.5	3		5
	2.0	3		4		3.7	3		4
No. 4	1.0	6	1	4	No. 11	1.0	3		6
	3.5	3		4		3.3	3		4
No. 5	.5	8		4	No. 12	.5	7	1.0	6
	1.0	5		4		3.8	4	2.5	6
	3.5	3		4		2.0	3	4.0	5
No. 6	2.0	6		4		4.0	3		4
	3.0	3		4	No. 13	2.5	4	1.0	6
No. 7	1.5	3	1	6		2.0	3	2.0	5
	2.0	3	2	5		3.0	3		4
	2.0	3		4					

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds*		
Main A	8.0	8	1	8	474	$2,503	$20,024
	1.5	7	1	6	289	1,526	2,289
Laterals	38.0	3		4	133	772	29,336
	1.0	5		4	163	847	847
	3.0	6		4	178	1,032	3,096
	.5	8		4	207	1,202	601
	17.8	3		5	194	1,178	20,968
	5.8	3		6	267	1,692	9,814
	6.3	4		6	289	1,831	11,535
	.5	7		6	356	2,256	1,128

Right of way 8 miles in length, 33 feet wide, Main A, 32 acres, at $30 per acre.	$960
Eight highway bridges, Main A, 192 feet, at $6 per foot	1,152
Contingencies, Main A	2,000
Right of way 48 miles in length, for ditches on quarter-section line, average width 24½ feet, laterals, 144 acres, at $30 per acre	4,320
Contingencies, laterals	8,000

Total cost for district:	
Improving Marais	$15,000
Main A	26,425
Laterals	89,645
Total	131,070
Cost per acre	2.26

BOWESMONT DISTRICT.

The greater part of the Bowesmont district is drained by ditches either completed or in process of construction, and only one lateral ditch has been planned.

Lateral.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*
No. 1	1	4	5	4
	3	3	5	4
	5	3	....	4

Summary of lateral.

Length.	Bottom width.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
Miles.	*Feet.*	*Feet.*	*Cu. yds.*		
8	3	4	133	$772	$6,176
1	4	4	148	859	859

Contingencies	$900
Total cost of laterals for district	7,935
Cost per acre	1.01

ZEBRA DISTRICT.

Zebra district covers an area of 48,000 acres. Main A drains 57,000 acres at the mouth, side slope 1 to 1; Main B drains 13,000 acres at the mouth, side slope 1½ to 1; Main C drains 11,500 acres at the mouth, side slope 1½ to 1; Main D drains 11,500 acres at the mouth, side slope 1½ to 1; Main E drains 11,500 acres at the mouth, side slope 1½ to 1; Main F drains 7,500 acres at the mouth, side slope 1½ to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	1.5	3	....	5	No. 5	1.0	6	1	
	2.0	3	....	4		2.5	3	....	5
No. 2	1.5	3	....	5	No. 6	2.0	3	....	4
	2.0	3	....	4	No. 7	3.5	3	....	4
No. 3	2.5	3	....	4	No. 8	3.75	4	....	4
No. 4	2.0	3	....	4					4

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade. per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	4.0	16	1.5	8	711	$3,754	$15,016
	5.0	14	1.0	8	652	3,442	17,210
	4.5	8	3.5	7	389	2,054	9,243
	4.5	6	5.0	6	267	1,410	6,345
	4.0	6	6.0	4	148	781	3,124
Main B	1.0	10	1.0	6	422	2,674	2,674
	1.0	8	1.0	6	378	2,395	2,395
	2.0	6	1.0	6	333	2,110	4,220
Main C	1.0	10	1.0	6	422	2,674	2,674
	1.0	8	1.0	6	378	2,395	2,395
	2.0	6	1.0	6	333	2,110	4,220
Main D	1.0	10	1.0	6	422	2,674	2,674
	1.0	8	1.0	6	378	2,395	2,395
	1.0	6	1.0	6	333	2,110	2,110
Main E	1.0	6	3.0	5	250	1,518	1,518
	1.0	5	4.0	5	232	1,409	1,409
	1.0	4	4.0	5	213	1,294	1,294
Main F	1.0	6	7.0	4	178	1,032	1,032
	1.0	6	3.0	4	178	1,032	1,032
Laterals	16.5	3	....	4	133	772	12,738
	3.0	3	....	5	194	1,178	3,534
	3.75	4	....	4	148	860	3,225
	1.0	6	....	5	250	1,518	1,518

Additional cost of extra cutting through ridge east of slough, Main A	$8,000
Right of way 22 miles in length, 33 feet wide, Main A, 88 acres, at $30 per acre	2,640
Twenty-two bridges, Main A, 560 feet, at $6 per foot	3,360
Contingencies, Main A	6,000
Right of way 4 miles in length, 33 feet wide, Main B, 16 acres, at $30 per acre	480
Three bridges, Main B, 78 feet, at $6 per foot	468
Contingencies, Main B	1,000
Right of way 4 miles in length, 33 feet wide, Main C, 16 acres, at $30 per acre	480
Three bridges, Main C, 78 feet, at $6 per foot	468
Contingencies, Main C	1,000
Right of way 3 miles in length, 33 feet wide, Main D, 12 acres, at $30 per acre	360
Three bridges, Main D, 78 feet, at $6 per foot	468
Contingencies, Main D	800
Right of way 3 miles in length, 33 feet wide, Main E, 12 acres, at $30 per acre	360
Three bridges, Main E, 60 feet, at $6 per foot	360
Contingencies, Main E	500
Right of way 2 miles in length, 25 feet wide, Main F, 6 acres, at $30 per acre	180
Two bridges, Main F, 36 feet, at $6 per foot	216
Contingencies, Main F	300
Contingencies, laterals	2,200

Total cost for district:

Main A	70,938
Main B	11,237
Main C	11,237
Main D	8,807
Main E	5,441
Main F	2,760
Laterals	23,215
Total	133,635
Cost per acre	2.78

HAMILTON DISTRICT.

Hamilton district covers an area of 48,000 acres. Main A drains 48,000 acres at the mouth, side slope 1 to 1; Main B drains 9,000 acres at the mouth, side slope 1½ to 1; Main C drains 12,000 acres at the mouth, side slope 1½ to 1.

Laterals.

Lateral.	Length.	Bottom width.	Depth.	Lateral.	Length.	Bottom width.	Depth.
	Miles.	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*
No. 1	1.5	3	4	No. 5	1.5	3	5
No. 2	2.3	3	4		3.0	3	4
No. 3	2.0	3	5	No. 6	2.0	3	5
	2.0	3	4		3.0	3	4
No. 4	2.5	3	4	No. 7	2.5	6	5

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	2.5	14	1.5	8	652	$3,442	$8,605
	6.0	12	1.0	8	593	3,131	18,786
	3.5	8	3.0	6	311	1,642	5,747
	5.0	6	5.0	6	204	1,077	5,385
Main B	1.5	8	1.0	6	378	2,395	3,592
	1.0	4	1.0	5	213	1,294	1,294
Main C	1.5	10	1.0	6	422	2,674	4,011
	1.0	4	1.0	6	289	1,831	1,831
Laterals	14.3	3	....	4	133	772	11,039
	5.5	3	....	5	194	1,178	6,479
	2.5	6	....	5	250	1,518	3,795

Right of way 17 miles in length, 33 feet wide, Main A, 68 acres, at $30 per acre.	$2,040
Seventeen bridges, Main A, 400 feet, at $6 per foot	2,400
Contingencies, Main A	3,500
Right of way 2.5 miles in length, 33 feet wide, Main B, 10 acres, at $30 per acre.	300
Three bridges, Main B, 70 feet, at $6 per foot	420
Contingencies, Main B	450
Right of way 2.5 miles in length, 33 feet wide, Main C, 10 acres, at $30 per acre.	300
Three bridges, Main C, 78 feet, at $6 per foot	468
Contingencies, Main C	500
Contingencies, laterals	2,100

Total cost for district:

Main A	46,463
Main B	6,056
Main C	7,110
Laterals	23,413
Total	83,042
Cost per acre	1.73

BATHGATE DISTRICT.

Bathgate district covers an area of 12,000 acres lying in the bend of the Tongue River. Main A drains 12,000 acres at the mouth, side slope 1½ to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*
No. 1	3.0	5	4	4
	3.0	4	....	4
No. 2	1.5	4	....	4
	2.0	3	....	4
No. 3	1.8	3	....	4

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	0.8	6	2	6	333	$2,110	$1,688
	1.2	6	2	5	250	1,518	1,822
	2.3	5	2	5	232	1,409	3,241
Laterals	3.8	3	....	4	133	772	2,934
	4.5	4	....	4	148	860	3,870
	3.0	5	....	4	163	847	2,541

Right of way 4.3 miles in length, 25 feet wide, Main A, 13 acres, at $30 per acre	$390
Three bridges, Main A, 66 feet, at $6 per foot	396
Contingencies, Main A	480
Contingencies, laterals	1,000
Total cost for district:	
Main A	8,017
Lateral	10,345
Total	18,362
Cost per acre	1.53

M'ARTHUR DISTRICT.

McArthur district covers an area of 29,000 acres lying between the Tongue and Red rivers. Main A drains 14,000 acres at the mouth, side slope 1½ to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1	2.2	4	1	6	No. 4	4.3	4	1	6
	1.0	3	....	5		2.0	3	....	5
No. 2	1.8	3	1	5	No. 5	1.0	3	....	4
No. 3	2.2	3	....	5	No. 6	2.5	4	1	5
	1.0	3	....	4					

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A	3	10	1	6	422	$2,674	$8,022
	2	8	1	6	378	2,395	4,790
	1	6	1	5	250	1,518	1,518
Laterals	2.0	3	....	4	133	772	1,544
	7.0	3	....	5	194	1,178	8,246
	2.5	4	....	5	213	1,294	3,235
	6.5	4	....	6	289	1,831	11,901

Right of way, 6 miles in length, 33 feet wide, Main A, 24 acres, at $30 per acre	$720
Five bridges, Main A, 131 feet, at $6 per foot	786
Contingencies, Main A	1,300
Contingencies, laterals	2,500
Total cost for district:	
Main A	17,136
Laterals	27,426
Total	44,562
Cost per acre	1.54

HALLSON DISTRICT.

Hallson district covers an area of 9,000 acres. Tongue River drains 128,000 acres at the mouth, side slope 1 to 1.

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Tongue River	6.6	16	10	8	711	$3,754	$24,776
Lateral	2	6	9	4	178	1,032	2,064

Right of way, 6.6 miles in length, 33 feet wide, Tongue River, 26.4 acres, at $30 per acre	$792
Seven bridges, Tongue River, 224 feet, at $6 per foot	1,344
Contingencies, Tongue River	2,100
Contingencies, lateral	200
Total cost for district:	
Tongue River	29,012
Lateral	2,264
Total	31,276
Cost per acre	3.48

TONGUE RIVER.

Improvement of the Tongue River would benefit approximately 8,000 acres, at a cost of $3.60 per acre. As few ditches as practicable have been designed to outlet in the Tongue River, as it is not advisable to cut the river bank, for the channel is taxed to its full capacity to carry the water which comes through the sand ridge in Akra Township. It is thought that by constructing these ditches as outlined on the map and by clearing the channel of brush and other obstructions, the Tongue River, with some improvement in sections 8 and 9, Bathgate Township, and by reenforcing the banks at some of the low points with a light levee, flooding of the lands lying along each side of the stream will be prevented. The expense of this work should be paid by all the lands that are affected by the Tongue River overflows.

NECHE DISTRICT.

Neche district covers an area of 72,000 acres lying between the Tongue and Pembina rivers. Main A drains 77,000 acres at the mouth, side slope 1 to 1; Main B drains 29,000 acres at the mouth, side slope 1½ to 1; Main C drains 24,000 acres at the mouth, side slope 1 to 1.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.	Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*	*Feet.*
No. 1......	1.5	4	3	5	No. 3......	2.5	6	3	5
	3.0	4	....	4		2.0	5	3	5
No. 2......	1.5	4	3	5		3.0	4	....	4
	2.0	4	....	4	No. 4......	2.0	4	....	4

Dimensions and cost of mains and laterals.

Ditch.	Length.	Bottom width.	Grade per mile.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*		
Main A..............................	2.0	24	1	10	1,260	$6,653	$13,306
	3.0	12	3	10	815	4,303	12,909
	5.0	10	3	8	533	2,814	14,070
	5.0	8	4	8	474	2,503	12,515
	4.0	8	10	6	311	1,642	6,568
Main B............................	2.5	8	6	6	378	2,395	5,987
	6.0	6	4	6	333	2,110	12,660
Main C..............................	1.75	8	1	8	474	2,503	4,380
	3.50	7	4	7	363	1,917	6,709
	2.00	7	5	7	363	1,917	3,834
	.75	10	1	7	200	1,056	792
	3.50	6	3	6	267	1,410	4,935
	[a] 2.00	4	5	5	213	1,294	2,588
	[a] 2.00	4	5	4	148	860	1,720
Laterals....	2.50	6	....	5	250	1,518	3,795
	2.00	5	....	5	232	1,409	2,818
	3.00	4	....	5	213	1,294	3,882
	10.00	4	....	4	148	860	8,600

[a] Side slope 1½ to 1.

Right of way 19 miles in length, 33 feet wide, Main A, 76 acres, at $30 per acre	$2, 280
Twenty bridges, Main A, 534 feet, at $6 per foot	3, 204
Contingencies, Main A	5, 200
Right of way 8.5 miles in length, 33 feet wide, Main B, 34 acres, at $30 per acre	1, 020
Eight bridges, Main B, 200 feet, at $6 per foot	1, 200
Contingencies, Main B	1, 700
Right of way 15½ miles in length, 33 feet wide, Main C, 62 acres, at $30 per acre	1, 860
Twelve bridges, Main C, 239 feet, at $6 per foot	1, 434
Contingencies, Main C	3, 000
Contingencies, laterals	2, 000
Total cost for district:	
Main A	70, 052
Main B	22, 567
Main C	31, 252
Laterals	21, 095
Total	144, 966
Cost per acre	2. 01

PEMBINA DISTRICT.

Pembina district covers an area of 14,000 acres.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*
No. 1	4. 0	10	1. 0	6
	2. 0	8	1. 0	6
	3. 0	6	3. 0	4
No. 2 [a]	4. 5	6	. 6	6

[a] No. 2 is intended to serve for lateral drainage and to act as an overflow ditch to keep the water from rising in the slough in section 3 at the high-water period when the flood gate into the Pembina River is closed.

Summary of laterals.

Length	Bottom width.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
Miles.	*Feet.*	*Feet.*	*Cu. yds.*		
4. 0	10	6	422	$2, 674	$10, 696
2. 0	8	6	378	2, 395	4, 790
4. 5	6	6	333	2, 110	9, 495
3. 0	6	4	178	1, 032	3, 096

Contingencies	$3, 000
Total cost of laterals for district	31, 077
Cost per acre	2. 22

WALHALLA DISTRICT.

Walhalla district covers an area of 22,000 acres in Pembina County and approximately 8,000 acres in Cavalier County. Each ditch is designed to carry the drainage of its natural watershed to the west.

Laterals.

Lateral.	Length.	Bottom width.	Grade per mile.	Depth.
	Miles.	*Feet.*	*Feet.*	*Feet.*
No. 1	8	6	6	6
	4	5	....	
No. 2	7	8	7	
	4	6	....	

Summary of laterals.

Length.	Bottom width.	Depth.	Excavation per 100 feet.	Cost per mile.	Total cost.
Miles.	*Feet.*	*Feet.*	*Cu. yds.*		
7	8	6	378	$2,395	$16,765
12	6	6	333	2,110	25,320
4	5	6	311	1,970	7,880

Contingencies	$5,000
Total cost of laterals for district	54,965
Cost per acre	1.83

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